

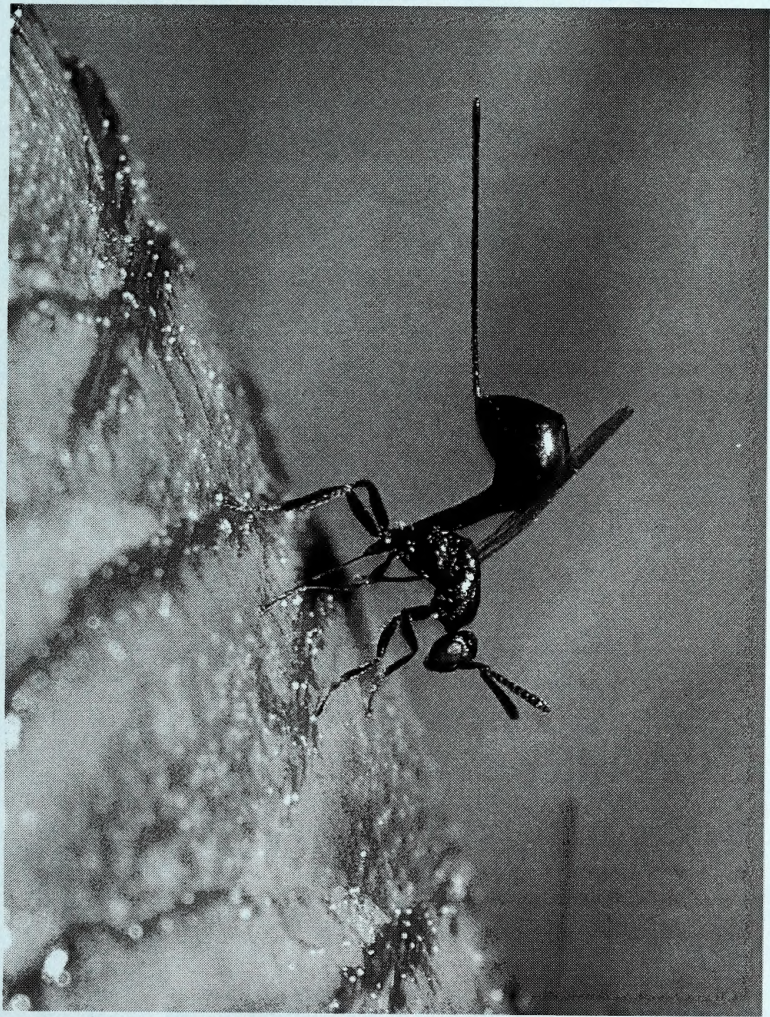
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COVER: *Torymus azureus* (Hymenoptera: Torymidae)

This 3-mm wasp is drilling with her ovipositor into a developing spruce cone which has been infested by the galling midge *Kaltenbachiola rachiphaga* (Diptera: Cecidomyiidae). Her larvae will parasitize the midge larvae, providing a measure of biological control against the cecidomyiid.

Photograph details:

Cover image by Ward Strong. Kalamalka Seed Orchards, Vernon, BC.

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Seasonal patterns of capture of *Helicoverpa zea* (Boddie) and *Heliothis phloxiphaga* (Grote and Robinson) (Lepidoptera: Noctuidae) in pheromone traps in Washington State.

L. CAMELO¹, T. B. ADAMS², P. J. LANDOLT³, R. S. ZACK⁴, and C. SMITHISLER

ABSTRACT

In each of the 6 years of this study in south central Washington state, male corn earworm moths, *Helicoverpa zea* (Boddie), first appeared in pheromone traps in late May to mid June, and thereafter were present nearly continuously until mid to late October. Maximum numbers of male corn earworm moths captured in pheromone traps occurred in August and early September. Male *Heliothis phloxiphaga* (Grote and Robinson) moths first appeared in traps baited with corn earworm pheromone and conspecific pheromone in April, and were generally present throughout the season until mid to late September. In some years, two peaks of trap capture of *H. phloxiphaga* males was suggestive of two generations per season, with one flight in April and May and the other in July and August. Although both species were caught primarily in traps baited with their appropriate conspecific pheromone, smaller numbers of both species were captured in traps baited with the heterospecific pheromone. *Heliothis phloxiphaga* captured in corn earworm pheromone traps can be misidentified as corn earworm, resulting in false positives for corn earworm in commercial sweet corn or overestimates of corn earworm populations.

Key Words: Seasonal phenology, *Helicoverpa zea*, *Heliothis phloxiphaga*, corn earworm, trapping, pheromone

INTRODUCTION

Helicoverpa zea (Boddie), the corn earworm (CEW), is a pest of many agricultural crops, particularly corn, tomato, and cotton (Metcalf and Metcalf 1993). The moth is monitored in cropping systems with a four component sex pheromone (Klun *et al.* 1980). In the irrigated farming areas of south central Washington, the corn earworm is the key pest of sweet corn, and numerous pesticide applications are required per season to control it. *Heliothis phloxiphaga* (Grote and Robinson) is generally not a pest but is important as a non-target insect that is sometimes captured in corn earworm pheromone traps (Adams 2001, Hoffman *et al.* 1991). *Heliothis phloxiphaga* males respond to the corn earworm pheromone, due to the overlapping chemistries of pheromones of these two species (Kaae *et al.* 1973, Klun *et al.* 1980, Raina *et al.* 1986). Because of their

overlapping size and coloration, *H. phloxiphaga* in CEW pheromone traps may be wrongly identified, giving false positive indications for CEW and potentially leading to unnecessary pesticide applications (Adams 2001, Hoffman *et al.* 1991). Photographs of the adult stage of both species are figured by Covell (1984), Powell and Opler (2010), and on the Noctuoidea of Canada Website (Troubridge and Lafontaine 2011).

Monitoring of the male corn earworm moth flight with pheromone traps provides information to growers and field scouts that is used to make pest management decisions. Growers of sweet corn in Washington use the traps to indicate the onset of arrival of corn earworm moths, and the need to begin a spray program. In this area, the corn earworm has one to three generations per year (Mayer *et al.* 1987), while *H. phloxiphaga* may be

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univoltine (Piper and Mulford 1984). Sweet corn is first planted in May in eastern Washington, becomes susceptible to attack by the corn earworm in mid July, and is grown by staggered planting dates into October. Growers need to know when to expect corn earworm moth flight, and when to be concerned with distinguishing corn earworm from *H. phloxiphaga* moths in corn earworm pheromone traps. Seasonal patterns of corn earworm captures in traps have been determined for other geographic and climactic areas (Parajulee *et al.* 2004, Weber and Ferro 1991) but these reports may not be applicable to irrigated agriculture of Washington.

MATERIALS AND METHODS

Trapping studies were conducted in 1999 to 2004 in south central Washington. The multicolored (white bucket with yellow cone and green lid) Universal Moth Trap (Great Lakes IPM, Vestaburg, MI) was used, with a 6.4 cm² piece of Vaportape™ (Hercon Environmental, Emigsville, PA) stapled to the inside wall of the trap bucket to kill captured insects. In all cases, traps were checked and captured insects removed each week, and Vaportape™ and lures were replaced every 4 weeks.

Corn earworm lures were the pheromone identified by Klun *et al.* (1980) consisting of 86.7% (Z)-11-hexadecenal, 3.3% (Z)-9-hexadecenal, 1.7% (Z)-7-hexadecenal, and 8.3% hexadecanal in a total pheromone load of 1.0 mg per septum, following the methods of Halfhill and McDunough (1985). Pheromone lures for *H. phloxiphaga* (Raina *et al.* 1986) were 92% (Z)-11-hexadecenal, 0.4% (Z)-9-hexadecenal, 4.8% hexadecanal, and 2.8% (Z)-11-hexadecen-1-ol in a total pheromone load of 1.0 mg per septum. Pheromone was loaded into red rubber septa (West Co., Lyonville, PA) that had been pre-extracted twice with methylene chloride in a tumbler. Pheromone was applied to septa as a solution in hexane, at a dosage of 200 microliters per septum. Chemicals were purchased from Farchan Chemicals (Atlanta, GA) and Aldrich Chemical Co. (Milwaukee, WI), and all chemicals were 95% or greater purity. The aldehydic pheromone compounds were purified by elution through a silica gel column with 5% ether in hexane. Pheromone

The primary objective of this study was to determine the seasonal occurrences of adult *H. zea* and *H. phloxiphaga* in central Washington. We determined seasonal patterns of moths present as indicated by captures of moths in pheromone-baited traps. In addition, we note responses of the two species to their conspecific and heterospecific sex pheromones. Differences and similarities in the seasonal patterns of the two species should help with interpretation of trap catch data and reduce errors caused by the capture of both species in traps used for corn earworm pest management programs.

dispensers were stored in glass vials in a freezer until placed in traps in the field. Pheromone lures were placed in the plastic baskets provided at the center of the inside of the tops of the traps

Traps were set up early in the season near fields to be planted to corn, and were maintained until the moth flights ended in late autumn. Traps were either hung on fences or from stakes put into the ground, at a height of 0.7 to 1.0 m. Traps were checked each week, and Vaportape™ and pheromone lures were replaced each month. Moths in traps were placed in labeled Ziploc® plastic bags for transport to the laboratory, where moths were sorted, identified, and counted. Voucher specimens are deposited in the James Entomological Collection, Department of Entomology, Washington State University, Pullman, WA.

Season-long monitoring of CEW with pheromone traps. Corn earworm moths were trapped throughout the seasons of 1999-2004, with from 4 to 9 trap sites used per season (Table 1). One trap baited with corn earworm pheromone was placed at each site. Trapping sites were selected based on abundant acreage of commercial sweet corn to be planted nearby. At the end of the season, traps were recovered from the field, washed with hot soapy water, rinsed with tap water, and exposed outside to sun and open air in wooden bins for a minimum of 30 days before indoor winter storage, to reduce risk of long term contamination of the trap by pheromone.

Season-long monitoring of *H.*

***phloxiphaga* with pheromone traps.** *Heliothis phloxiphaga* moths were monitored with traps baited with *H. phloxiphaga* pheromone, during 1999-2001. Trapping sites, trapping dates, and trap maintenance were the same as those indicated above for corn earworm pheromone traps during the same years (Table 1). One trap baited with *H. phloxiphaga* pheromone was placed at each site, more than 90 meters from the corn

earworm pheromone trap.
We also report *H. phloxiphaga* moths captured in traps baited with CEW pheromone from 1999-2004, and CEW moths captured in traps baited with *H. phloxiphaga* pheromone, from 1999-2001. Statistical comparisons were made of numbers of CEW and *H. phloxiphaga* moths trapped in response to conspecific versus heterospecific sex pheromone lures, using a paired t-test.

Table 1.
Dates and lures for season long monitoring of corn earworm.

Year	Start Date	No. of Sites	Site Locations	Pheromones tested
1999	17 May	9	Yakima Co., Mabton & Toppenish Benton Co., Prosser	CEW <i>H. phloxiphaga</i>
2000	20 April	5	Grant Co., Mattawa	CEW <i>H. phloxiphaga</i>
2001	16 April	4	Grant Co., Moses L. Franklin Co., Pasco	CEW <i>H. phloxiphaga</i>
2002	25 March	4	Yakima Co., Wapato, Granger, Donald, Toppenish	CEW
2003	29 March	4	Yakima Co., Toppenish & Moxee Benton Co., Prosser	CEW
2004	2 April	4	Yakima Co., Toppenish & Moxee Benton Co., Prosser	CEW

RESULTS

Generally, first male corn earworm moths were captured in late May, and males were present continuously through the summer into October (Figure 1). In all years, maximum numbers of male moths were captured in August. However, in 2002 and 2003, a smaller peak of activity was apparent in June. Numbers of moths per trap per week varied widely from year to year, with a maximum of over 250 per trap per week in 2002, but under 70 moths per trap per week in 1999, 2000, and 2003.
For 1999-2001, data for *H. phloxiphaga* are from traps baited with conspecific pheromone, and for 2002-2004, data for *H. phloxiphaga* are from traps baited with CEW pheromone. Generally, male *H. phloxiphaga* moths were first captured in pheromone traps in April (Figure 2). In 1999 and 2000, traps were not placed in the field early enough to

determine the onset of *H. phloxiphaga* flight and males were captured during the first week of the study. In all 6 years, there were two separate periods of flight activity of male *H. phloxiphaga*. The first period was in late April to early June, and the second period was mid July to late August. Numbers of moths trapped varied greatly from year to year, with a maximum of over 24 male moths per trap per week in 2004, and a maximum of fewer than 5 moths per week in 1999.
Traps baited with CEW pheromone captured primarily CEW moths, and traps baited with *H. phloxiphaga* pheromone captured primarily *H. phloxiphaga* (Table 2). In 1999, 2000, and 2001, when the pheromones of both CEW and *H. phloxiphaga* were maintained throughout the season, CEW moths were captured primarily in traps baited with the CEW pheromone, with relatively few

captured in traps baited with the *H. phloxiphaga* pheromone. Numbers of male *H. phloxiphaga* captured were numerically but not significantly greater in traps baited with

the *H. phloxiphaga* pheromone compared to traps baited with the CEW pheromone (Table 2).

DISCUSSION

The primary objective of this study was to characterize the seasonal patterns of captures of CEW and *H. phloxiphaga* moths in traps in southcentral Washington as an indicator of adult moth presence in corn fields. Particular aspects of moth seasonal patterns that are potentially of interest include the onset of moth flight in the spring and cessation in autumn, peak activity periods, and numbers of generation per year. In this case, we are also

interested in determining periods of risk of misidentifying *H. phloxiphaga* as CEW, in relation to CEW pest management. Although numbers of CEW moths captured in pheromone traps varied greatly from year to year, the cessation, termination, and peak periods of moth activity were similar throughout this 6 year period. The period during which corn earworm moths were active broadly encompasses the entire period during

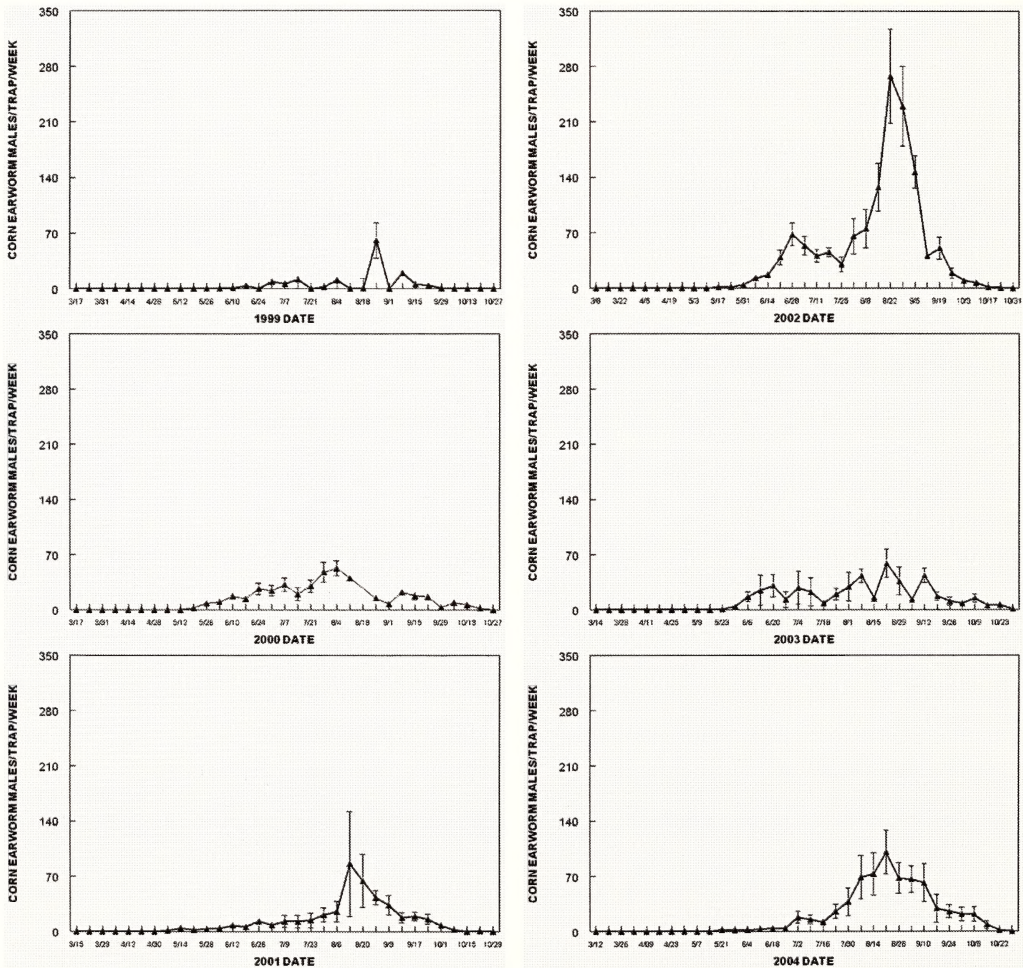


Figure 1. Mean (\pm SE) numbers of male corn earworm moths captured per week per trap, in traps baited with corn earworm pheromone, for 1999, 2000, 2001, 2002, 2003, and 2004.

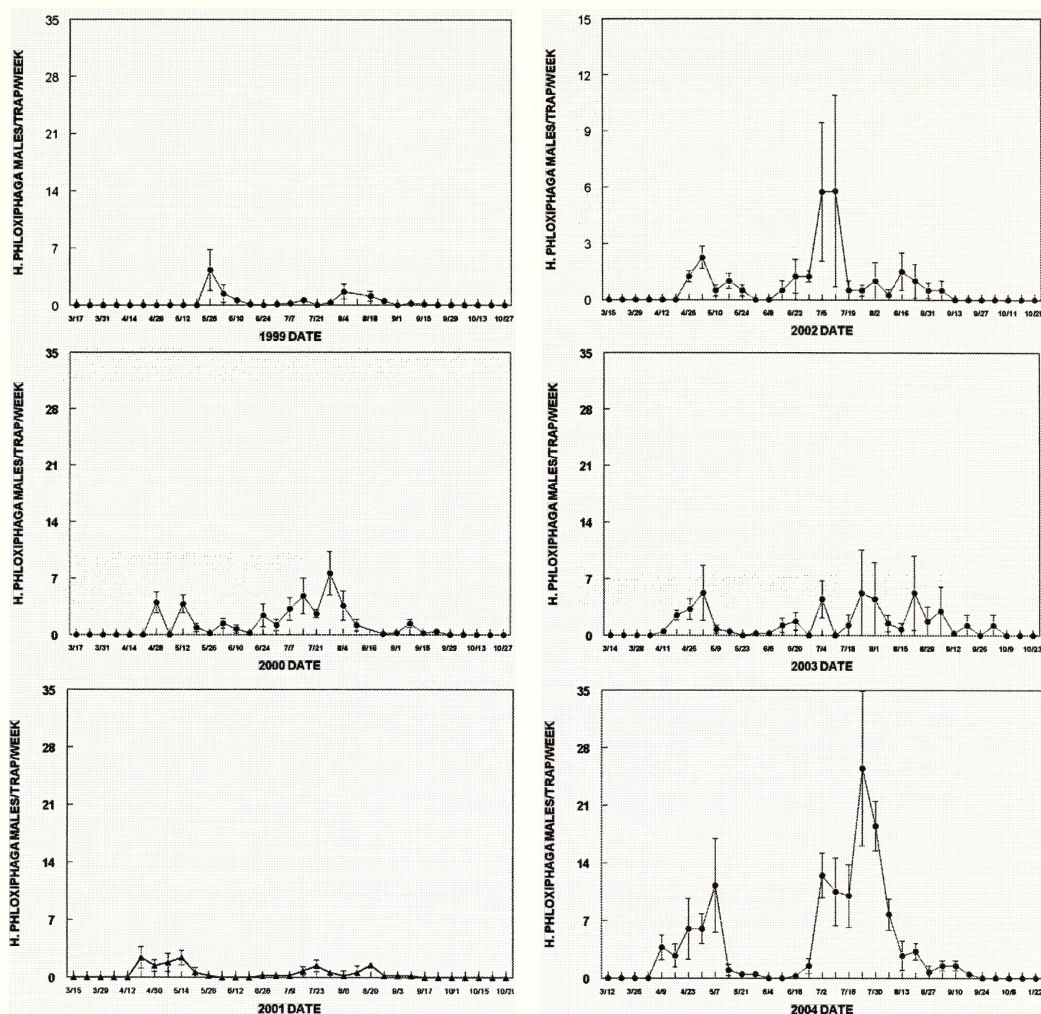


Figure 2. Mean (\pm SEM) numbers of male *H. phloxiphaga* moths captured per week per trap, in traps baited with *H. phloxiphaga* pheromone (1999, 2000 and 2001) or corn earworm pheromone (2002, 2003, 2004).

which corn is grown in this same area. Corn is normally first planted after last frost, in mid to late May, and staggered plantings and harvesting continue into early October. However, corn is a suitable oviposition site for CEW beginning with the silking stage, which starts in late June. Earlier in the season, CEW moths might be infesting alternate host plants, possibly weed and wild flower species (Hardwick 1965, 1996; Neunzig 1963; Robinson *et al.* 2002). It is assumed that the end of moth flight in autumn may occur primarily as a result of decreasing temperatures making moth flight impossible. In contrast to evidence for CEW migrating

from south to north (Hartstack *et al.* 1982; Westbrook *et al.* 1997), there is no documentation of north to south migration. If such a migration occurs, it could explain in part the disappearance of the moth in early autumn in south central Washington.

Mayer *et al.* (1987) reported 1-3 generations of CEW per year in Washington. Our data show nearly continuous moth activity for 5 months, from late May into mid to late October, without evidence of distinct generations. Corn earworm may overwinter in the southern Columbia Basin of Washington, as pupae in soil (Eichman 1940, Klostermeyer 1968), first emerging in May. The

interpretation of trap catch data may be complicated by immigration of CEW populations from the southwestern U. S. In other areas of North America, CEW moths migrate (Hartstack *et al.* 1982; Hendrix *et al.* 1987; Lingren *et al.* 1993, 1994; Westbrook *et al.* 1997). Strong increases in numbers of male CEW moths in pheromone traps in August may have been due to reproduction by earlier emerging moths, and/or migrating moths that arrive in south central Washington with infrequent weather fronts.

The seasonal activity and abundance of the corn earworm moth varies geographically, probably in response to climactic factors and their impact on migration, reproduction, and other behaviors, as well as regional makeup and abundance of crops and crop planting and harvest cycles. The amplitudes of the seasonal patterns of catches of CEW moths in pheromone traps in south central Washington were small compared to that observed in Texas by Parajulee *et al.* (2004). Captures of moths in pheromone traps often began in April in Texas, compared to May in Washington, and ended in October as it did in our study in Washington. In Mississippi, CEW males were

captured in pheromone traps sporadically from early June to the end of September (Hayes 1991). In Massachusetts, CEW moth flight appears to begin much later than in south central Washington despite a similar latitude. Weber and Ferro (1991) captured CEW moths in pheromone traps in Massachusetts from early July into early September, which is a seasonal activity period that is nearly 2 months shorter than seen in our study.

Piper and Mulford (1984) reported that *H. phloxiphaga* was univoltine in Washington. The data presented here indicate consistently over the 6 years that there were two periods of increased catches of moths in traps, indicating possibly two generations per year. The apparent two maxima of activity indicated by pheromone traps suggests that a first adult generation occurred in April/May and a second generation in July/August. However, Hoffman *et al.* (1991) did not see more than one peak of captures of *H. phloxiphaga* in corn earworm pheromone traps in California, although adult activity was noted over a period of 6 months, from February to September. Certainly, multiple generations of a moth species can occur within a season

Table 2
Mean (\pm SE) numbers of male corn earworm and *H. phloxiphaga* moths captured per season per trap baited with corn earworm and *H. phloxiphaga* sex pheromones.

Moth species captured	Corn earworm pheromone	<i>H. phloxiphaga</i> pheromone	n
1999			
Corn earworm	218.3 \pm 64.2a	1.4 \pm 1.1b	9
<i>H. phloxiphaga</i>	6.9 \pm 2.4a	12.4 \pm 3.9a	9
2000			
Corn earworm	427.6 \pm 52.3a	3.8 \pm 1.0b	5
<i>H. phloxiphaga</i>	25.2 \pm 6.4a	44.2 \pm 10.9a	5
2001			
Corn earworm	415.8 \pm 144.0a	2.5 \pm 0.9b	4
<i>H. phloxiphaga</i>	22.3 \pm 5.7a	16.0 \pm 5.8a	4

Means within a row followed by the same letter are not significantly different by a paired t-test at P < 0.05.

without the appearance of distinct separated periods of flight indicated in pheromone traps.

In all six years of our study, the first flight of *H. phloxiphaga* began about one month before the first catches of CEW moths in traps, and captures of *H. phloxiphaga* moths ended about one month before the last captures of CEW moths. Peak numbers of possible second flight *H. phloxiphaga* populations overlapped somewhat with peak numbers of CEW in early August, although the numbers of *H. phloxiphaga* in *H. phloxiphaga* pheromone traps were considerably less than CEW moths trapped with corn earworm pheromone. It appears then that CEW monitoring traps in May might easily provide misleading information from the capture of *H. phloxiphaga* misidentified as CEW, but before the expected appearance of CEW. Also, in August, *H. phloxiphaga* captured in CEW pheromone traps may inflate counts of CEW trap catch, if misidentified. However, those numbers would usually be minor in relation to the numbers of CEW moths trapped at that time. It is most important to positively identify the two species early in the season, and again in late

summer when both are present, but in situations where corn earworm populations are expected to be low.

Although the chemistry of the *H. phloxiphaga* sex pheromone overlaps with that of the CEW pheromone, *H. phloxiphaga* responses to the CEW lure are not consistently a problem with CEW monitoring programs in North America. Weber and Ferro (1991) found 5 non-target species of noctuids captured in CEW monitoring traps in Massachusetts, but did not indicate the trapping of *H. phloxiphaga*. Chapin *et al.* (1997) reported non-target moths captured in corn earworm traps, but captured only one *H. phloxiphaga* moth compared to over 25,000 CEW. However, in eastern Washington, *H. phloxiphaga* is consistently present throughout much of the corn growing season and is routinely captured in corn earworm pheromone traps (Adams 2001), and Hoffman *et al.* (1991) trapped it in sweet corn fields throughout California. Growers can reduce costs and pesticide used by distinguishing the two species when captured in corn earworm traps, and by recognizing that corn earworm are unlikely to be present before late May.

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Occurrence of the Western Flower Thrips, *Frankliniella occidentalis*, and potential predators on host plants in near-orchard habitats of Washington and Oregon (Thysanoptera: Thripidae)

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ABSTRACT

One hundred thirty species of native and introduced plants growing in uncultivated land adjacent to apple and pear orchards of central Washington and northern Oregon were sampled for the presence of the western flower thrips (WFT) *Frankliniella occidentalis* (Pergande, 1895) and potential thrips predators. Plants were sampled primarily while in flower. Flowering hosts for WFT were available from late-March to late-October. Adult WFT occurred on 119 plant species and presumed WFT larvae were present on 108 of 119 species. Maximum observed WFT density on several plant species exceeded 100 individuals (adults and larvae) per gram dry weight of plant material. The most abundant predator was *Orius tristicolor* (White, 1879) (Heteroptera: Anthracoridae). It was collected on 64 plant species, all of which were hosts for WFT. The second most abundant predators were spiders (Araneae). Small spider immatures (first and second instars) of several species were common on certain host plants, and are likely to feed on WFT.

Key Words: *Frankliniella occidentalis*, western flower thrips, host plants, predators, *Orius tristicolor*, Araneae, spiders.

¹INTRODUCTION

The western flower thrips (WFT) *Frankliniella occidentalis* (Pergande, 1895), was originally distributed throughout western North America (Kirk and Terry 2003). In the past 30 years WFT has spread to much of the rest of North America and now also occurs throughout Europe and parts of North Africa (Kirk and Terry 2003). It is a pest in both the field and the greenhouse, attacks a large number of crops, and causes damage by feeding, oviposition, and most importantly, transmission of Tospoviruses (Reitz 2009). WFT is an important secondary pest of certain apple varieties in the Pacific Northwest, producing a pale, cosmetic blemish known as a pansy spot that forms around the site of oviposition (Venables 1925; Madsen and Jack 1966). Although the damage is superficial, affected fruit may be downgraded at harvest (Madsen and Jack 1966; Terry 1991). Control of WFT on apple can be challenging because it occurs on trees primarily when pollinators,

especially honeybees, *Apis mellifera* Linnaeus, 1758, are active in the orchard canopy. It has also been difficult to determine when, during fruit formation, damage-causing oviposition occurs and, consequently, when control measures are most needed (Cockfield *et al.* 2007).

Host plant utilization by WFT is very broad. Bryan and Smith (1956) found it on 139 plant species (representing 45 families) in California, which is within the pest's original geographic range. In areas to which it has spread, host plant utilization is also broad, and in Hawaii it was found on 48 plant species on the island of Maui (Yudin *et al.* 1986). Chellemi *et al.* (1994) found it on 24 of 37 plant species surveyed in Florida within a decade after its first detection. In a study done barely ten years after the insect was first reported all 49 plant species sampled in Turkey harbored WFT (Atakan and Uygun 2005). In Chile, where it has become a serious

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agricultural pest, WFT occurred on 50 of 55 plant species and appears to have supplanted a native species of *Frankliniella* as the most common thrips species (Ripa *et al.* 2009).

A number of predators are known to attack WFT (Sabelis and Van Rijn 1997). Few of the studies that have reported on WFT's occurrence on non-crop plant species have also reported on the presence of predator species. Northfield *et al.* (2008) studied the population dynamics of WFT on seven uncultivated host plants and also reported on the occurrence of the important thrips predator *Orius insidiosus* (Say, 1832) (Heteroptera: Anthocoridae). Tommasini (2004) monitored *Orius* populations on known host plants of WFT in Italy and found that several species of *Orius* commonly occurred at high densities on

a number of these host plants, apparently in association with WFT.

In this study, we surveyed native and introduced plant species in fruit-growing regions of central Washington and northern Oregon where WFT is a secondary pest of certain apple varieties. Our objectives were to 1) gain an understanding of WFT utilization of non-cultivated host plants typical of near-orchard habitats in the study areas, 2) develop a better understanding of WFT phenology across the season, and 3) improve our understanding of known and potential WFT predators occurring on these non-cultivated host plants, with emphasis on minute pirate bugs (Heteroptera: Anthocoridae) and spiders (Araneae).

MATERIALS AND METHODS

Study Sites. This study was conducted at 11 sites in Washington State and two sites in northern Oregon (Table 1). Virtually all sampling was done in native habitat immediately adjacent to orchards, generally within 100 m of an orchard edge; a few plant species of interest that occurred in the understory of orchards were also sampled. Most of the sites were in Yakima County, Washington, located in the south-central part of the state. Two sites were near Hood River in northern Oregon (Table 1).

With one exception, each tract of native habitat was at least several hectares in area and adjacent to orchard habitat. The only exception was a tract comprising a 25 m wide strip of native vegetation occurring between an orchard and an irrigation canal. Native habitat at all Yakima County and the Grant County locales was sagebrush steppe (Table 1). Sagebrush steppe at Hambleton, Durey, and Sunset fell within the lithosol zone of Taylor (1992), and is characterized by thin, rocky soils and a diverse flora. In mid-May at these locations we noted 25 or more plant species in flower simultaneously. Sagebrush steppe at the remaining Yakima County sites and the Grant County site fell within the standard-type zone (Taylor 1992), characterized by moderately deep soil and vegetation dominated by grasses and tall sagebrush, *Artemisia tridentata* Nutt. (Asteraceae). The Ing, Wells, and Alway sites

consisted of mixed hardwood/coniferous woodland. Trees included *Pinus ponderosa* Dougl. (Pinaceae), *Pseudotsuga menziesii* (Mirbel) Franco (Pinaceae), *Acer macrophyllum* Pursh (Aceraceae), and *Quercus garryana* Dougl. (Fagaceae). Understories at all three sites consisted of a variety of shrubs and forbs.

Sampling for thrips and predators. The Yakima County study sites were visited at approximately weekly intervals during 2002 from early April to late October. Due to greater travel distances the Grant County site was visited bi-weekly, and the Chelan County and Oregon sites were visited monthly from April to July. Sampling in 2003 was limited to selected plant species (see below) at sites in Yakima County. Durey and Hambleton were visited weekly from late March to late October, while the other Yakima County sites were visited when species of interest were in flower. During each visit, observations were made of plants in flower and whether a species was at early, full, or late bloom. Notes were also made of species that had recently passed out of bloom and of those that were about to come into bloom.

Samples were collected by removing inflorescences or individual flowers with scissors or pruning shears and immediately placing them in 3.8L, self-sealing, plastic bags. Care was taken when removing flowers to avoid dislodging insects and spiders. Since

Table 1.
Sampling sites, habitat type at each site, and sampling frequencies.

Site	Location (county)	Habitat	Sampling frequency ¹	
			2002	2003
Hambleton	3.5 km N Tieton (Yakima)	Sagebrush-steppe	W	W
Durey	4.5 km NNW Tieton (Yakima)	Sagebrush-steppe	W	W
Sunset	4.5 km S Tieton (Yakima)	Sagebrush-steppe	W	I
Carlson	3 km SSE Union Gap (Yakima)	Sagebrush-steppe	W	I
Leach	6 km NNE Zillah (Yakima)	Sagebrush-steppe	W	I
Lynch	5.5 km NE Zillah (Yakima)	Sagebrush-steppe	W	I
Hattrup	5 km SSE Moxee (Yakima)	Sagebrush-steppe	W	I
Valicoff	6.5 km SSE Moxee (Yakima)	Sagebrush-steppe	W	I
USDA	18 km ESE Moxee (Yakima)	Sagebrush-steppe	W	I
Knutson	10 km SE Mattawa (Grant)	Sagebrush-steppe	BW	--
Alway	Peshastin (Chelan)	Mixed hardwoods and conifers	M	--
Ing (Oregon)	2 km SSE Hood River (Hood River)	Mixed hardwoods and conifers	M	--
Wells (Oregon)	6 km SSE Hood River (Hood River)	Mixed hardwoods and conifers	M	--

¹ W, weekly; BW, bi-weekly; M, Monthly; I, irregularly.

WFT is primarily associated with flowers, non-flower plant parts such as leaves and stems were kept to a minimum in samples during the bloom periods. Samples taken outside of the bloom period included primarily rapidly growing vegetative tissue. Samples were transported in a cooled ice chest to the laboratory where they were held in a refrigerated room until processed, generally within 24 h. The amount of plant material collected for a sample varied from species to species depending upon its abundance at a site and the nature of its inflorescence. Abundant species with large or bulky inflorescences were collected in sufficient quantity to loosely fill a bag. Smaller quantities were obtained of

less abundant species and those with small, more difficult to collect flowers. Blooms were collected from several individual plants per species at a site to obtain a sample. The number of individual plants sampled per species depended upon the density of that species at the site.

We were interested in each plant species primarily during its bloom period. A single, flowering period sample was obtained for some species, but many were sampled more than once during bloom. Several species were sampled weekly while in flower with additional samples taken during the pre-bloom and post-bloom periods. The extreme example was bitterbrush *Purshia tridentata* (Pursh) DC

(Rosaceae), which was sampled weekly at the Durey site from 16 April to 28 October 2003, for a total of 29 sample dates. Most species were sampled at one or two locations, but samples from arrowleaf balsamroot *Balsamorhiza sagittata* (Pursh) Nutt. (Asteraceae), a common, widespread species, were obtained at nine sites. In 2002, most of the plant species at each site were sampled on at least one date. Based on the 2002 findings, 16 species that supported high numbers of thrips and predators were monitored in 2003.

Extraction of arthropods. Thrips and predatory arthropods were extracted from plant material using Berlese funnels. Heat from 40 watt light bulbs was used to force arthropods out of the plant material and into 500 ml plastic jars each containing 50 ml of 70% isopropyl alcohol. Samples were held in the funnels for 24–48 h depending on the quantity of plant material. This length of time was sufficient to dry the plant material, which was then weighed on an electronic balance. We calculated thrips numbers per gram dry weight of plant material.

Processing of samples. WFT was the only thrips identified to species (by comparison with vouchers). Species other than WFT were generally few in number (see Results). Larval thrips were counted but were not identified. When the adult thrips in a sample were exclusively WFT we assumed that all larval thrips were that species. If adults of more than one species were present the number of larval WFT was estimated based on the proportion

of adult WFT in the sample. If the number of thrips in a sample appeared to be less than 300, an exact count was made. For samples that obviously contained a greater number, the number of thrips was estimated by counting a subsample (an exception was made for the maximum density from each plant species, which was always determined by an exact count). To obtain estimates from subsamples, the thrips (in alcohol) were poured into a plastic Petri dish inscribed on the bottom with six squares each 1 cm x 1 cm in size. The dish was agitated until the thrips were distributed approximately uniformly over the bottom of the dish. The thrips within each square were counted, the average number per square was computed, and this average was multiplied by the area of the dish to obtain an estimate of the total.

Exact counts were made of all predators. For minute pirate bugs, *Orius* spp., the number of males, females, and each of the five nymphal instars was determined. Samples were composed almost entirely of *Orius tristicolor* (White, 1879), although scattered individuals of *Orius diespeter* Herring, 1966 were likely present in the Peshastin samples (Lewis *et al.* 2005). Immature spiders of several species were common in some samples. In most cases it was possible to identify these to species based on our familiarity with the local fauna. It was also possible to estimate the nymphal stage of many of these spiders based on comparison with reference specimens of known stage.

RESULTS

Host plant characteristics. One hundred and thirty plant species were sampled, representing 34 plant families and 101 genera (Table 2). Ninety-nine species were native to the study area, while 31 species were introduced. The Asteraceae was represented by the most species (32), and the wild buckwheat genus *Eriogonum* (Polygonaceae) was the best represented genus with seven species. Samples from red clover *Trifolium pratense* L., white clover *Trifolium repens* L., and alfalfa *Medicago sativa* L. (all Fabaceae) were collected only within orchards. Plant growth form varied, but perennial forbs were the most common (62 species) followed by shrubs (20 species) and annual forbs (16

species).

Host plant utilization by *Frankliniella occidentalis*. Adult WFT were extracted from 119 plant species, while thrips larvae were extracted from 108 of these same 119 species (Table 2). Plant species that harbored both adult and larval WFT are assumed to be reproductive hosts for the insect. Of the 11 species that did not yield WFT, eight were sampled only once, five have rather small or inconspicuous flowers, and one blooms early in the spring. Two of the species that did not yield WFT, (*Lomatium triternatum* (Pursh) Coult. and Rose and *Erigeron pumilus* Nutt.) had congeneric species that yielded both adult WFT and larval thrips. It is likely that more

Table 2

Plant species sampled for *Frankliniella occidentalis* (WFT) indicating presence (+) or absence (-) of WFT and presumed WFT larvae. Max. WFT density is the maximum density (# of adults plus larvae per gram dry weight of plant material) recorded for a plant based on an exact count. Abbreviations: N= native species; I= introduced species; F= forb; H= herb; S= shrub; T= tree; V= vine; A= annual; B= biennial; P= perennial.

Host plant	Plant Origin	Type of plant	WFT adults	WFT larvae	Max. WFT density	No. of samples
ACERACEAE						
<i>Acer macrophyllum</i> Pursh	N	T	+	-	0.7	2
APIACEAE						
<i>Daucus carota</i> L.	I	BF	+	+	0.2	1
<i>Lomatium columbianum</i> Mathias and Constance	N	PF	+	+	0.5	1
<i>Lomatium grayi</i> Coult. and Rose	N	PF	+	+	21.6	8
<i>Lomatium nudicaule</i> (Pursh) Coult. and Rose	N	PF	+	+	0.2	2
<i>Lomatium triternatum</i> (Pursh) Coult. and Rose	N	PF	-	-	0	1
APOCYNACEAE						
<i>Apocynum androsaemifolium</i> L.	N	PF	+	+	24.8	5
ASCLEPIADACEAE						
<i>Asclepias speciosa</i> Torr.	N	PF	+	+	255.9	8
ASTERACEAE						
<i>Achillea millefolium</i> L.	N	PF	+	+	62.5	63
<i>Agoseris glauca</i> (Pursh) Raf.	N	PF	+	+	0.2	2
<i>Ambrosia artemisiifolia</i> L.	I	AF	+	+	1.2	1
<i>Artemisia tridentata</i> Nutt.	N	S	+	+	30.4	80
<i>Artemisia</i> sp.	N	S	+	+	15.3	6
<i>Balsamorhiza hookeri</i> Nutt.	N	PF	+	+	20.4	6
<i>Balsamorhiza sagittata</i> (Pursh) Nutt.	N	PF	+	+	27.8	57
<i>Centaurea cyanus</i> L.	I	AF	+	+	21.8	4
<i>Centaurea diffusa</i> Lam.	I	A/BF	+	+	9.9	13
<i>Chaenactis douglasii</i> (Hook.) Hook. and Arn.	N	B/PF	+	+	29.1	14
<i>Chrysothamnus viscidiflorus</i> (Hook.) Nutt.	N	S	+	+	58.7	84
<i>Cirsium arvense</i> (L.) Scopoli	I	PF	+	+	34.4	12
<i>Cirsium undulatum</i> (Nutt.) Spreng.	N	B/PF	+	+	1.8	2
<i>Crepis acuminata</i> Nutt.	N	PF	+	+	15.7	14
<i>Crepis occidentalis</i> Nutt.	N	A/PF	+	+	0.7	4
<i>Crocidium multicaule</i> Hook.	N	AF	+	-	11.4	1
<i>Dieteria canescens</i> (Pursh) Nuttall	N	B/PF	+	+	17	10
<i>Ericameria nauseosa</i> (Pall. ex Pursh) G. Nesom and G. Baird	N	S	+	+	132.2	76
<i>Erigeron filifolius</i> (Hook.) Nutt.	N	PF	+	+	10.5	8
<i>Erigeron linearis</i> (Hook.) Piper	N	PF	+	+	4.3	8
<i>Erigeron pumilus</i> Nutt.	N	PF	-	-	0	1
<i>Eriophyllum lanatum</i> (Pursh) J. Forbes	N	PF	+	+	0.3	5
<i>Helianthus cusickii</i> A. Gray	N	PF	+	+	61.1	7
<i>Iva axillaris</i> Pursh	N	PF	+	+	107.2	7

Host plant	Plant Origin	Type of plant	WFT adults	WFT larvae	Max. WFT density	No. of samples
<i>Lactuca serriola</i> L.	I	AF	-	-	0	6
<i>Layia glandulosa</i> (Hook.) Hook. and Arn.	N	AF	+	+	1.9	3
<i>Nothocalais troximoides</i> (A. Gray) Greene	N	PF	+	+	1.3	5
<i>Pyrrocoma carthamoides</i> Hook.	N	PF	+	+	0.6	8
<i>Senecio integerrimus</i> Nutt.	N	BF	+	+	6.2	4
<i>Solidago lepida</i> DC	N	PF	+	+	35.5	15
<i>Stephanomeria tenuifolia</i> (Raf.) H. M. Hall	N	PF	+	+	0.8	3
<i>Tragopogon dubius</i> Scop.	I	A/BF	+	+	13	8
BERBERIDACEAE						
<i>Berberis aquifolium</i> Pursh	N	S	+	+	0.8	5
BORAGINACEAE						
<i>Amsinckia lycopoides</i> Lehm ex Fisch. and C.A. Mey	N	AF	+	+	36.8	8
<i>Amsinckia tessellata</i> A. Gray	N	AF	+	+	62.1	10
<i>Cynoglossum grande</i> Dougl. ex Lehm.	N	PF	-	-	0	2
<i>Lithospermum ruderales</i> Dougl. ex Lehm.	N	PF	+	-	1.2	3
<i>Mertensia longiflora</i> Greene	N	PF	+	+	1	2
BRASSICACEAE						
<i>Chorispora tenella</i> (Pall.) DC	I	AF	+	-	0.4	1
<i>Descurania sophia</i> (L.) Webb and Prantl	I	AF	+	+	25.1	5
<i>Erysimum capitatum</i> (Dougl. ex Hook.) Greene	N	B/PF	+	+	2.2	2
<i>Lepidium perfoliatum</i> L.	I	A/BF	+	+	10.7	3
<i>Phoeniculis cheiranthoides</i> Nutt.	N	PF	+	+	7	1
<i>Sisymbrium altissimum</i> L.	I	A/BF	+	+	60.7	9
<i>Thelypodium laciniatum</i> (Hook.) Endl.	N	BF	+	+	27.5	4
CAPRIFOLIACEAE						
<i>Lonicera ciliosa</i> (Pursh) Poir. ex DC.	N	PV	-	-	0	1
<i>Sambucus cerulea</i> Raf.	N	S	+	+	31.7	4
<i>Symphoricarpos albus</i> (L.) Blake	N	S	+	+	6.2	8
CHENOPODIACEAE						
<i>Kochia scoparia</i> (L.) Schrad.	I	AF	+	+	30.4	8
<i>Chenopodium album</i> L.	I	AF	+	+	9	5
<i>Grayia spinosa</i> (Hook.) Moq.	N	S	+	+	18.2	10
<i>Salsola tragus</i> L.	I	AF	+	+	75.7	12
CLUSIACEAE						
<i>Hypericum perforatum</i> L.	I	PF	+	+	1.2	1
CORNACEAE						
<i>Cornus sericea</i> L.	N	S	+	+	<0.1	2
FABACEAE						
<i>Astragalus</i> sp.	N	PF	+	+	14.9	3
<i>Cytisus scoparius</i> (L.) Link	I	S	+	+	4.9	3
<i>Lupinus lepidus</i> Dougl. ex Lindl	N	PF	+	+	23	4
<i>Lupinus wyethii</i> Wats.	N	PF	+	+	36.9	10

[illegible]

Host plant	Plant Origin	Type of plant	WFT adults	WFT larvae	Max. WFT density	No. of samples
<i>Eriogonum compositum</i> Dougl. ex Benth.	N	PF	+	+	61.5	6
<i>Eriogonum elatum</i> Dougl.	N	PF	+	+	150.9	86
<i>Eriogonum heracleoides</i> Nutt.	N	PF	+	+	48.2	6
<i>Eriogonum microthecum</i> Nutt.	N	PF	+	+	35.8	15
<i>Eriogonum niveum</i> Douglas ex Benth.	N	PF	+	+	23.4	7
<i>Eriogonum strictum</i> Benth.	N	PF	+	+	76.4	4
<i>Eriogonum thymoides</i> Benth.	N	PF	+	+	1.1	4
<i>Rumex crispus</i> L.	I	PF	+	+	12.9	7
RANUNCULACEAE						
<i>Clematis ligusticifolia</i> Nutt.	N	PV	+	+	77.1	28
<i>Delphinium nuttallianum</i> Pritz. ex Walp.	N	PF	+	+	0.9	3
RHAMNACEAE						
<i>Ceanothus integerrimus</i> Hook. & Arn.	N	S	+	+	4.1	6
<i>Ceanothus velutinus</i> Dougl. ex Hook.	N	S	+	+	0.1	2
<i>Frangula purshiana</i> (DC.) Cooper	N	S/T	+	+	2.5	2
ROSACEAE						
<i>Amelanchier alnifolia</i> (Nutt.) Nutt. ex M. Roemer	N	S/T	+	+	0.4	6
<i>Crataegus douglasii</i> Lindl.	N	S/T	+	-	<0.1	2
<i>Holodiscus discolor</i> (Pursh) Maxim.	N	S	+	+	40.3	3
<i>Prunus avium</i> (L.) L.	I	T	+	+	11.2	4
<i>Prunus emarginata</i> (Dougl. ex Hook.) D. Dietr.	N	S/T	+	+	0.5	2
<i>Prunus virginiana</i> L.	N	S/T	+	-	1.4	4
<i>Purshia tridentata</i> (Pursh) DC	N	S	+	+	18.7	71
<i>Rosa woodsii</i> Lindl.	N	S	+	+	88.7	11
<i>Rubus armeniacus</i> Focke	I	S/V	+	+	23.4	4
RUBIACEAE						
<i>Galium aparine</i> L.	N	AF	-	-	0	1
SALICACEAE						
<i>Salix exigua</i> Nutt.	N	S/T	+	+	57.7	15
SANTALACEAE						
<i>Commandra umbellata</i> (L.) Nutt.	N	PF	+	+	0.9	7
SAXIFRAGACEAE						
<i>Heuchera cylindrica</i> Dougl. ex Hook.	N	PF	+	-	0.6	2
<i>Lithophragma parviflorum</i> (Hook.) Nutt.	N	PF	-	-	0	2
SCROPHULARIACEAE						
<i>Castilleja thompsoni</i> Pennell	N	PF	+	+	34.1	9
<i>Collinsia parviflora</i> Lindl.	N	AF	-	-	0	1
<i>Linaria dalmatica</i> (L.) Mill.	I	PF	+	+	1.2	2
<i>Penstemon humilis</i> Nutt. ex Gray	N	PF	+	+	8.8	6
<i>Verbascum blattaria</i> L.	I	BF	+	-	0.1	1
<i>Verbascum thapsus</i> L.	I	BF	+	-	<0.1	2
URTICACEAE						
<i>Urtica dioica</i> L.	N	PF	+	+	9.3	1

intensive sampling would have found WFT on both *L. triternatum* and *E. pumilus*.

Frankliniella occidentalis reached very high densities on some host plants, exceeding 100 individuals per gram dry weight of plant material in samples from eight species (Table 2). Many of our nearly 1200 samples contained several thousand thrips. For example, an exact count of thrips from an 86.2 g sample of flowering *Ericameria nauseosa* (Pall. ex Pursh) G. Nesom and G. Baird (Asteraceae) yielded 10,320 adult WFT, 26 unidentified adult thrips, and 1,079 larvae. A 25.2 g sample of flowering *Asclepias speciosa* Torr. (Asclepiadaceae) produced 5,503 adult WFT, 26 unidentified adults, and 951 larvae. This was the highest density recorded during the study, at 255.9 WFT per gram of plant tissue. WFT was by far the most abundant species of Thysanoptera on the majority of the host plants sampled during this study. Samples from *Eriogonum elatum* Dougl. (Polygonaceae) (86 samples over two years) yielded 26,255 total adult thrips and 61,162 larvae. Only an estimated 143 adults (<1%) were not WFT.

These other thrips included a species tentatively identified as another *Frankliniella*. This thrips occurred on most Asteraceae and in some samples equaled or exceeded WFT in number. The most extreme example was *Pyrrocoma carthamoides* Hook. (Asteraceae). This plant was sampled for eight consecutive weeks in 2002 from the pre-bloom stage to the post-bloom stage. Although WFT was found in each sample it was greatly exceeded in abundance by the second putative *Frankliniella* species. Other genera of Thysanoptera were also abundant on occasion. A species of *Haplothrips* (probably *Haplothrips verbasci* (Osborn, 1897); Horton and Lewis 2003) was dominant on *Verbascum thapsus* L. (Scrophulariaceae). A sample of *V. thapsus* late in its 2002 flowering period yielded 1040 *Haplothrips* (adults and larvae) but only four WFT.

Plant phenology and thrips counts. We present phenology data from two extensively sampled sites (Durey and Hambleton; Table 1) west of Tieton (Fig. 1); the two sites are separated by approximately 1 km. Plant diversity was high in the habitat adjacent to the orchards at both sites. Plants in flower were present at the two sites on all dates

between early-April and mid-October (Fig. 1). Species that bloomed early included *Balsamorhiza sagittata* and other forbs. Late-flowering species included *Chrysothamnus viscidiflorus* (Hook.) Nutt. (Asteraceae) and *Eriogonum microthecum* Nutt. (Polygonaceae) (Fig. 1). One plant species, *Eriogonum elatum*, had a very long flowering period, first showing blooms in late-June and flowering well into October (Fig. 1).

WFT was present, often in large numbers, throughout the sampling period at these sites (Fig. 1). Generally, WFT occurred at only low densities on plants in the weeks preceding bloom. WFT density increased during the flowering period, and larval thrips greatly outnumbered adults in some samples from some plant species. For example, a peak bloom sample from *Phacelia hastata* Dougl. ex Lehm. (Hydrophyllaceae) yielded 297 WFT adults and 2594 thrips larvae. Post-bloom densities of thrips were usually low, and the near disappearance of the insect during the immediate post-bloom period could be rapid (see also section on thrips and predator phenology, below). The perennial *E. elatum* was notable for its lengthy flowering period and relatively high densities of thrips. Throughout the flowering period WFT was present at densities as high as 150.9 per gram dry weight of *E. elatum* plant material. Densities on *E. elatum* remained high well into October when most other plant species had passed out of bloom (Fig. 1). From late June to late September larvae usually outnumbered adults and comprised up to 90% of a sample. Since WFT were virtually the only adult thrips in our samples most larvae were undoubtedly this species. Thus *E. elatum* appears to be an excellent reproductive host for WFT.

Shrubs, which remain relatively green and succulent throughout the season, often supported WFT even when not in flower. *Chrysothamnus viscidiflorus*, *Ericameria nauseosa*, and *Artemisia tridentata* flower in late-summer or fall, but pre-bloom samples as early as mid-May from all three species yielded WFT adults and thrips larvae at low densities (<1.0/gram dry weight).

Purshia tridentata presented an interesting case. *Purshia* flowers heavily for about four weeks in late-spring (Fig. 1). WFT density peaked late in the flowering period or during

early post-bloom and then declined gradually over the next several weeks. From mid-July to early-September it was present at very low densities, and no adults were found in some samples. Then, in mid-September, adults began to show up in increasing numbers and were present through the end of October (Fig. 1), despite the absence of blooms. These late season individuals were almost exclusively females. WFT was found in the surface soil and litter beneath *Purshia* shrubs in late autumn, apparently in preparation for overwintering (unpublished observations).

Predators of *Frankliniella occidentalis* and predator phenology. Minute pirate bugs (*O. tristicolor*) were the most abundant thrips predators collected. Adult and/or nymphal pirate bugs were collected from 64 host plants (Table 3) all of which also hosted WFT. *Orius* generally attained its highest densities on host plants that also supported high densities of WFT, such as *Achillea*, *Medicago*, *Eriogonum*, *Clematis*, and *Trifolium* (Tables 2 and 3). Plants on which both insects reached high densities tended to have long flowering periods, and 18 of the 20 species on which the

highest WFT densities were recorded had flowering periods lasting a minimum of four weeks. A second factor that may contribute to high *Orius* and WFT densities on some plants may be flowering phenology. *Chrysothamnus viscidiflorus*, *Ericameria nauseosa*, and *Artemisia tridentata* flowered during late summer and fall. This phenological pattern may have tended to concentrate insects on these plants because fewer species are in flower so late in the season (Fig. 1).

Orius phenology appeared to track bloom and thrips phenology. The phenologies of the bloom, the WFT, and *Orius* on three plant species chosen because of differences in flowering times are compared in Figure 2: *Achillea millefolium* L. (Asteraceae) (early bloom), *Chrysothamnus viscidiflorus* (late bloom), and *Eriogonum elatum* (season-long bloom). The samples were obtained at the Hambleton site in 2002. Densities of *Orius* appeared to peak during bloom, and at or just following peak numbers of thrips (Fig. 2). Densities of both insect species declined rapidly following bloom. In Figure 3, we show age structure of the *Orius* specimens for each

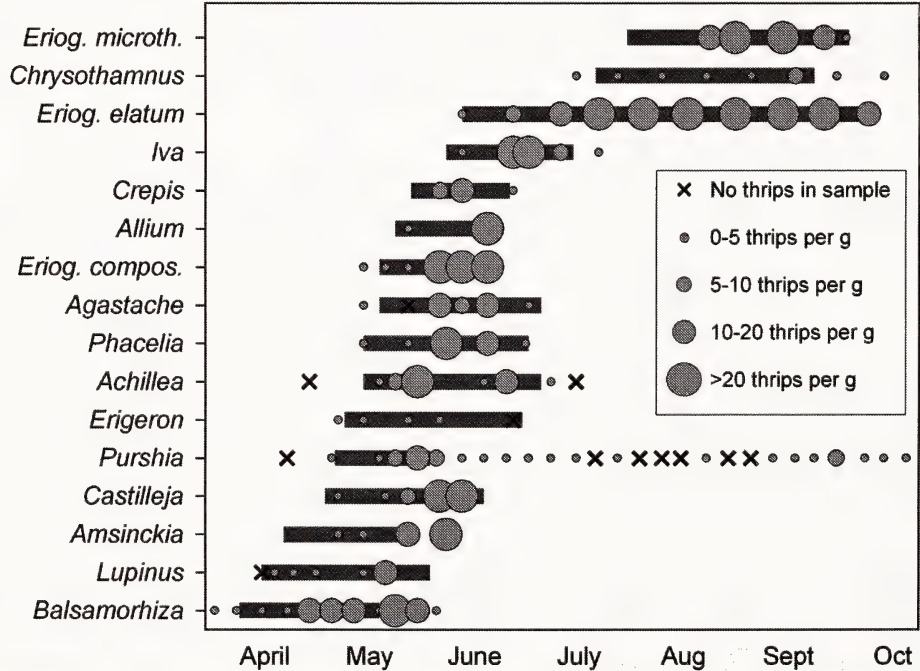


Figure 1. Flowering periods (shaded bars) of selected WFT host plants based on the Durey and Hambleton sites near Tieton, WA, and densities of WFT in pre-bloom, bloom, and post-bloom collections. Most plant species occurred at both sites.

of these host plants. Adults and nymphs were present in virtually all samples in which *Orius* was collected. The results for *E. elatum* suggest that *Orius* completed two generations on this one host species (Fig. 3). Females dominated the last two collections on *E. elatum* (Fig. 3).

The other common taxon of predators found during this study was the Araneae. Eleven families and at least 20 genera of spiders were collected from 69 plant species (Table 3). The spiders occurred in large numbers and considerable diversity on several plant species. In general, those plant species on which WFT was abundant also had high spider abundance.

Several spider species were found on certain host plants primarily as first and second instar spiderlings (Table 3). Because of their small size, prey for these young spiders is probably restricted to small arthropods. Given its great abundance on many of the host plants, WFT would appear to provide a readily available supply of prey for these small predators. Thirty-seven plant species had one or more spider genera represented by small spiderlings, among the more important plants being *Achillea*, *Chrysothamnus*, *Medicago*, *Agastache*, *Eriogonum elatum*, and *Clematis*. Small crab spiderlings in the genus *Xysticus* (Thomisidae), especially *Xysticus cunctator* (Thorell, 1877), occurred on 33 of the plants. A second thomisid, *Misumenops lepidus* (Thorell, 1877), was found as small spiderlings on 13 plants.

Generally, positive species identification of spiders requires examination of adults. Because of our familiarity with the local fauna, however, we were able to identify many of the immatures in our samples. The genus *Xysticus* was represented primarily by *X. cunctator*, *Misumenops* by *M. lepidus*, and *Sassacus* (Salticidae) by *Sassacus papenhoei* Peckham and Peckham, 1895. Local

Phidippus species (Salticidae) are difficult to distinguish during the first two or three instars. Based upon our knowledge of the local fauna, the *Phidippus* complex in our samples probably included *Phidippus johnsoni* (Peckham and Peckham, 1883), *Phidippus comatus* Peckham and Peckham, 1901, *Phidippus clarus* Keyserling, 1885, and *Phidippus audax* (Hentz, 1845). All seven of these species occur in local orchards.

Predators other than *Orius* and spiders were found on 38 species of plants, but were uncommon compared to those two groups. Fourteen insect families were represented. Predaceous Miridae (*Deraeocoris brevis* (Uhler, 1904) and *Campylomma verbasci* (Meyer-Dür, 1843)) were extracted from 18 host plants. Several species of lady-beetle adults and larvae (Coccinellidae) were extracted from 17 plant species, but the number found in a given sample was rarely more than five individuals. The next most common families were: Geocoridae (found on 13 plant species), Chrysopidae (9), Hemerobiidae (6), Anthoridae (*Anthocoris* spp.) (6), Phymatidae (6), Nabidae (6), and Reduviidae (5). The remaining families were each taken on only one or two plant species: Raphidiidae, Melyridae, Syrphidae, Coniopterygidae, and Cleridae.

Ants (Formicidae) occurred in samples from 64 plant species and were represented primarily by workers, although an occasional alate form was taken. The number of specimens in a sample was rarely more than two or three, and many collections from host plants sampled multiple times contained no specimens. For example, 56 samples were collected from *Artemisia tridentata* at seven sites in 2002, but ants occurred in only two of them. Some ant species are predaceous, but we made no attempt at identification below the family level.

DISCUSSION

The western flower thrips, causative agent of pansy spot on apple, was found on 92% of the plant species sampled in near-orchard habitats during this study. These results (indicating a broad utilization of available, non-cultivated host plants) are in agreement with findings from other parts of the thrips'

native range (Bryan and Smith 1956; Yudin *et al.* 1986) and also regions into which WFT has been introduced (Chellemi *et al.* 1994; Atakan and Uygur 2005). Madsen and Jack (1966), Pearsall (2000), and Cockfield *et al.* (2007) reported WFT from a number of non-cultivated host plants in near-orchard habitats

Table 3

Occurrence and maximum density (# per gram dry weight of plant material) of *Orius* spp. and spiders on sampled host plants. Maximum spider density includes all spiders found in the sample. Plants on which neither *Orius* nor spiders were found are not included. *Orius* stages: m=male; f=female; 1, 2, 3, 4, 5 indicate the five nymphal instars. Abbreviations for spider taxa: A=*Anyphaena*; Ar=*Araneidae*; C=*Coriarachne*; D=*Dictynidae*; E=*Ebo*; H=*Hololena*; Ha=*Habronattus*; L=*Linyphiidae*; M=*Misumenops*; Mi=*Misumena*; O=*Oxyopes*; P=*Phidippus*; Pe=*Pelegrina*; Ph=*Philodromus*; Ps=*Phanias*; S=*Sassacus*; T=*Theridion*; Te=*Tetragnatha*; Ti=*Tibellus*; X=*Xysticus*. ¹Indicates a spider taxon represented primarily by 1st and 2nd instar spiderlings. See text for further explanation.

Host plant	<i>Orius</i> stages present	Max. <i>Orius</i> density	Spider taxa present	Max. spider density
<i>Acer</i>	--	--	L	<0.1
<i>Daucus</i>	5	0.1	M ¹	0.2
<i>Lomatium grayi</i>	--	--	D	<0.1
<i>L. columbianum</i>	--	--	L	<0.1
<i>Apocynum</i>	m,2,3,4	<0.1	X ¹ ,M,D,L	<0.1
<i>Asclepias</i>	f,m,3,4,5	0.6	X ¹ ,Ph,S,P,D	0.5
<i>Achillea</i>	f,m,1,2,3,4,5	2.9	X ¹ ,M ¹ ,S,P ¹ ,Pe,T,Ph,Mi,C,A,L,D	0.7
<i>Ambrosia</i>	f	<0.1	--	--
<i>Artemisia</i> sp.	f,m,2,4,5	0.3	X ¹ ,S,Pe	<0.1
<i>A. tridentata</i>	f,m,1,2,3,4,5	<0.1	X,M,S,Pe,T,Ph,L,D,H,Ha	0.2
<i>Balsamorhiza hookeri</i>	3,4	<0.1	M	<0.1
<i>B. sagittata</i>	f,m,1,2,3,4,5	0.6	M,S,T,O,L	0.1
<i>Centaurea cyanus</i>	--	--	Ar	<0.1
<i>C. diffusa</i>	f,m,2,3,5	0.1	--	--
<i>Chaenactis</i>	f,m,1,2,3,4,5	0.7	X ¹ ,M ¹ ,L	0.2
<i>Chrysothamnus</i>	f,m,1,2,3,4,5	2.3	X ¹ ,M ¹ ,S ¹ ,P ¹ ,Ph,Pe,D	0.4
<i>Cirsium arvense</i>	f,m,1,2,3,4,5	0.9	X ¹ ,M ¹ ,P ¹ ,Ph,A,D,L	0.4
<i>C. undulatum</i>	m,3,4	0.2	X ¹	0.1
<i>Crepis acuminata</i>	m,5	<0.1	X ¹ ,L	<0.1
<i>C. occidentalis</i>	m	<0.1	--	--
<i>Ericameria</i>	f,m,1,2,3,4,5	1.3	X,M ¹ ,S ¹ ,P,Pe,A,Ph,L,D	<0.1
<i>Erigeron filifolius</i>	2,3,4	0.4	--	--
<i>E. linearis</i>	2,3,5	0.4	X ¹	0.1
<i>Helianthus</i>	f,m,1,2,3,4,5	0.5	--	--
<i>Iva</i>	f,m,1,2,3,4,5	0.8	X ¹ ,L	<0.1
<i>Lactuca</i>	--	--	T	<0.1
<i>Layia</i>	--	--	M	<0.1
<i>Dieteria</i>	2	<0.1	D,L	0.1
<i>Nothocalais</i>	--	--	S	0.3
<i>Pyrrocoma</i>	f,1,2,5	<0.1	X,E	<0.1
<i>Solidago</i>	f,m,1,2,3,4,5	1.3	X ¹ ,M ¹ ,P,S,Pe,L	<0.1
<i>Tragopogon</i>	--	--	X ¹	<0.1
<i>Berberis</i>	--	--	T,O,L	<0.1
<i>Amsinckia lycopoides</i>	1,4	0.3	L	<0.1
<i>A. tessellata</i>	f,3,4,5	<0.1	X ¹ ,L	<0.1
<i>Descurania</i>	2	<0.1	--	--
<i>Lepidium</i>	--	--	L	<0.1
<i>Thelypodium</i>	2,3,4	0.2	--	--
<i>Lonicera</i>	--	--	T	<0.1
<i>Sambucus</i>	m	<0.1	--	--
<i>Symphoricarpos</i>	--	--	L	<0.1
<i>Kochia</i>	1,2	<0.1	M ¹ ,Pe	<0.1
<i>Chenopodium</i>	1,2,3,4,5	0.4	M,D	<0.1
<i>Grayia</i>	f,4	<0.1	--	--
<i>Salsola</i>	f,1,2,3,4,5	0.3	T,Ph,Ps,L,D	0.2
<i>Hypericum</i>	3,4,5	0.2	--	--

Host plant	<i>Orius</i> stages present	Max. <i>Orius</i> density	Spider taxa present	Max. spider density
<i>Lupinus lepidus</i>	3	<0.1	S	<0.1
<i>Medicago</i>	f,m,1,2,3,4,5	4.8	X ¹ ,M ¹ ,S ¹ ,Ph,Pe	<0.1
<i>Melilotus</i>	f,m,1,2,3,4,5	1.3	X ¹ ,S,Ph	<0.1
<i>Trifolium macrocephalum</i>	--	--	L	<0.1
<i>T. pratense</i>	f,1,2,3,4,5	1.7	P ¹	<0.1
<i>T. repens</i>	f,m,1,2,3,4,5	5.2	X ¹ ,M ¹ ,P ¹ ,Ph,T,L	0.2
<i>Ribes aureum</i>	--	--	M,T	<0.1
<i>R. cereum</i>	--	--	S	<0.1
<i>Philadelphus</i>	f,m	0.7	X ¹ ,S,Pe	<0.1
<i>Phacelia hastata</i>	f,m,2,3,4,5	0.8	X ¹ L	0.3
<i>P. linearis</i>	m,1	0.2	X ¹	0.2
<i>Agastache</i>	f,m,1,2,3,4,5	4.0	X ¹ ,M ¹ ,L	1.5
<i>Salvia</i>	f	<0.1	--	--
<i>Sphaeralcea grossulariifolia</i>	2,4,5	0.1	X ¹ ,M	<0.1
<i>S. munroana</i>	f,m,1,2,3,4,5	0.5	X ¹ ,Ph	<0.1
<i>Phlox hoodii</i>	f,2,4	<0.1	S,Ph,T,L	0.2
<i>P. longifolia</i>	f	<0.1	--	--
<i>Eriogonum compositum</i>	f,m,2,3,4,5	0.5	--	--
<i>E. elatum</i>	f,m,1,2,3,4,5	7.7	X ¹ ,M ¹ ,S ¹ ,P ¹ ,Pe ¹ ,O ¹ ,T,D,L	0.4
<i>E. heracleoides</i>	f,m,1,2,3,4,5	0.8	X ¹	<0.1
<i>E. microthecum</i>	f,m,1,2,3,4,5	0.3	X ¹ ,M,S ¹ ,P,Pe	0.1
<i>E. niveum</i>	f,m,1,2,4	0.1	M,S	<0.1
<i>E. strictum</i>	f,m,1,2,3,4,5	0.7	X ¹ ,L	0.2
<i>Rumex</i>	f,m,1,2,3,4,5	2.2	X ¹	<.1
<i>Clematis</i>	f,m,1,2,3,4,5	4.0	X ¹ ,M ¹ ,S ¹ ,P ¹ ,A ¹ ,D ¹ ,Pe,Ps,L	2.0
<i>Ceanothus integerrimus</i>	--	--	M,Mi,D	<0.1
<i>C. velutinus</i>	--	--	D	<0.1
<i>Frangula</i>	--	--	D	<0.1
<i>Crataegus</i>	--	--	H	<0.1
<i>Holodiscus</i>	5	<0.1	M,Pe	<0.1
<i>Purshia</i>	f,m,1,2,3,4,5	<0.1	X ¹ ,M,S,P ¹ ,Pe ¹ ,Ph,Ti,D,L	<0.1
<i>Rosa</i>	m,1	<0.1	X ¹ ,Pe,O,Ph,D,L	<0.1
<i>Rubus</i>	f,m,1,2,3,4,5	0.7	M	0.1
<i>Salix</i>	m,2,3	<0.1	D	<0.1
<i>Castilleja</i>	f,m,2,3,4,5	0.3	X ¹	<0.1
<i>Verbascum thapsus</i>	m,3,4,5	0.3	--	--
<i>Urtica</i>	f,1,2,3,4,5	2.6	X ¹	<0.1

of the Pacific Northwest and discussed implications for damage to apples and nectarines. Our study concentrated on plants growing outside of orchards, but several species that are common components of orchard understories, including red clover, white clover, and alfalfa, also supported large numbers of WFT. Venables (1925) remarked on the occurrence of WFT on alfalfa growing in orchards and its possible bearing on pansy spot of apple.

Frankliniella occidentalis, like other winged thrips, is a highly mobile insect, and

active or passive flights are the primary means of dispersal among thrips as a group (Lewis 1973). Gravid females of many species make local flights among host plants apparently as they search for oviposition sites (Lewis 1997). Flower-loving species like WFT may detect changes in the quality of these short-lived resources prompting movement within or between plants as their food value declines (Terry 1997). Madsen and Jack (1966), Cockfield *et al.* (2007), and Pearsall (2000) discussed movement of WFT between successively blooming host species and

flowering orchards. At some of our sites, dozens of host plant species were available over the course of the season in the near-orchard habitat, and additional species were present in the orchard ground cover.

Cultural control of WFT by elimination of alternate hosts does not seem to be a viable option (Cockfield *et al.* 2007), and alternate hosts that flower concurrently with the crop may even mitigate damage by diluting the thrips population (Beers *et al.* 1993). Pearsall (2000) did not believe that a trap crop would effectively reduce damage in nectarines. Natural enemies are rare in nectarine orchards in British Columbia during the spring (Pearsall 2000), and we noted few natural enemies in apple flowers (unpublished

observations). In apple orchards, careful monitoring of WFT densities and application of a suitable insecticide timed to eliminate females that are laying eggs on developing apples (while avoiding harm to pollinators) may be the best management approach (Madsen and Jack 1966; Cockfield *et al.* 2007). In some cases it may be possible to limit sprays to border rows (Miliczky *et al.* 2007).

Many of the same plants that were hosts for WFT also hosted known and potential thrips predators, sometimes in considerable numbers. *Orius* spp. are important thrips predators throughout the world (Lewis 1973). The minute pirate bug, *O. tristicolor*, was the most abundant predator on many plants

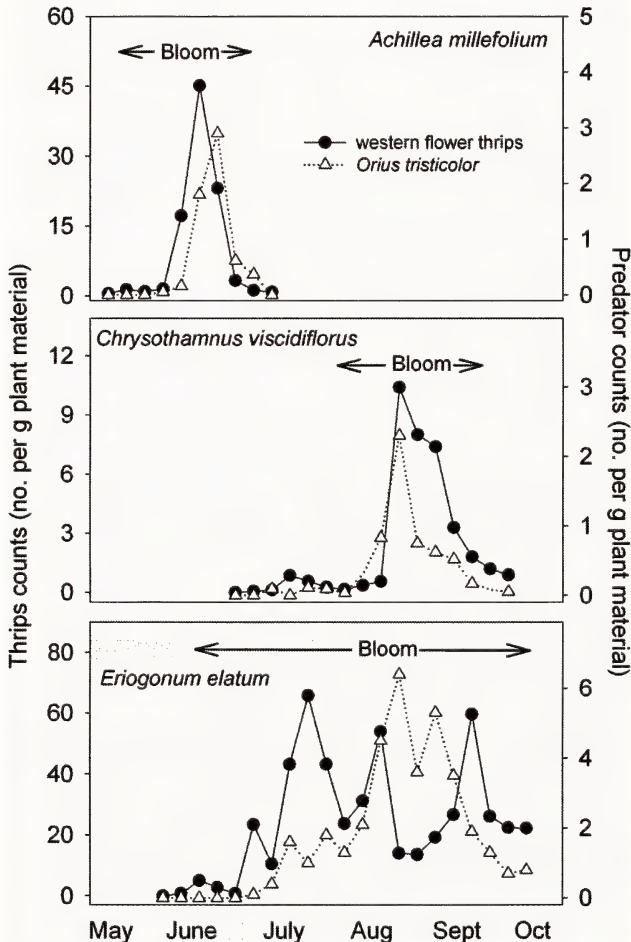


Figure 2. Correspondence between flowering period, WFT abundance, and abundance of the important thrips predator *Orius tristicolor* on three important WFT host plants in flower at different times during the season. Figure is based on 2002 data from the Hambleton site.

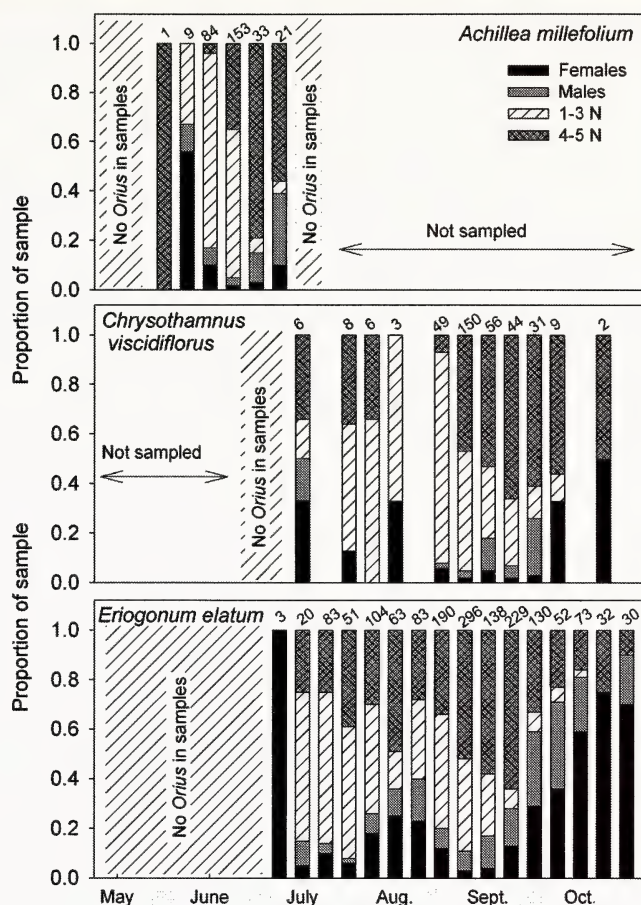


Figure 3. Age structure of *Orius tristicolor* in collections from the same three host plants as in Fig. 2 at the Hambleton site in 2002. Number at the top of each column indicates the total number of *Orius* in the sample.

sampled in this study. Barber (1936) noted that *O. insidiosus* could be “swept from almost any plant association”, and Kelton (1963) commented on the abundance of *Orius* spp. on the flowers of various plants. Numerous plant species supported populations of *O. insidiosus* near apple orchards in Virginia (including other crops and various weeds) (McCaffrey and Horsburgh 1986). Kakimoto *et al.* (2006) found a significant correlation between the density of *Orius sauteri* (Poppius, 1909) and thrips on spring weeds in Japan. Tommasini (2004) showed that non-cultivated host plants of WFT in Italy also supported species complexes of minute pirate bugs. *Orius tristicolor* occurred on 32 flowering plant species in north-central California, in all cases feeding on thrips, most frequently WFT (Salas-Aguilar and Ehler

1977). The early-season presence of thrips in Indiana soybean fields led to colonization of the crop by *O. insidiosus* and, in some years, the predator was then able to hold the later arriving soybean aphid *Aphis glycines* Matsumura, 1917 at low levels (Yoo and O’Neil 2009).

While *Orius* seem to prefer thrips as prey, they are generalist predators and a variety of other small prey items including mites, aphids, scale insects, leafhoppers, and Lepidoptera eggs and larvae are fed upon (McCaffrey and Horsburgh 1986). Pirate bugs may feed and partially develop on pollen (Kiman and Yeargan 1985; McCaffrey and Horsburgh 1986). Thus, an association with flowers gives *Orius* spp. access to both animal and plant food.

Sabelis and Van Rijn (1997) noted that

surprisingly little was known about spider predation on thrips, although they predicted that thrips were most likely to be important components of the diets of smaller species. Thrips comprised 9% of the prey of the small, cribellate spider *Dictyna arundinacea* (Linnaeus, 1758) (Heidger and Nentwig 1985), and webs of *Dictyna coloradensis* Chamberlin, 1919 often captured thrips, most of which were probably WFT (Miliczky and Calkins 2001). A recent greenhouse study using caged pepper plants infested with WFT indicated that in the presence of second instar *Xysticus kochi* Thorell, 1872, thrips damage to the peppers was reduced, and the peppers produced were of higher quality (Zrubecz *et al.* 2008).

The present study indicates that at certain times when thrips are abundant, they likely comprise a substantial portion of the diet of the early instars of various spiders. Early instars of these spiders, because of small size, are restricted to small prey. Due to the nature of the sampling procedure employed in this study actual predation of thrips by spiders was not observed. However, during a previous study (Miliczky and Horton 2007) in which beneficial arthropods were collected by beating several of the same plant species at the

same locations, small spiderlings of the species referred to above were observed with thrips prey in their mouthparts (unpublished observations).

In summary, the great majority of flowering plant species that occur in uncultivated land adjacent to eastern Washington apple orchards, as well as some ground cover species within the orchards, are hosts to WFT. WFT colonizes host species primarily while they are in flower, reproduces on many of them, and often reaches very high population levels. Small, immature spiders (especially first and second instars) of several species were numerous on some of the same plant species. WFT, because of its small size, great abundance, and ubiquitous occurrence is probably an important component in the diet of these small, young spiders, which because of their size, are restricted to suitably small prey. These spiders, as they mature and grow, will switch to larger prey. *Orius tristicolor*, an important thrips predator, occurs on many of the same plant species as WFT, is also able to reproduce on many of them, and builds up high numbers on some species. Both WFT and *O. tristicolor* appear to track available host plants, moving from one to the other as successive species come into flower.

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Drymus brunneus (Sahlberg) (Hemiptera: Rhyparochromidae): a seed bug introduced into North America

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ABSTRACT

The occurrence of the adventive *Drymus brunneus* (Sahlberg) in North America is documented, and characteristics to distinguish this Old World species from *D. unus* (Say) are described and illustrated. A revised key to the Western Hemisphere species of *Drymus* is included.

INTRODUCTION

Elsewhere (Scudder and Footitt 2006) reported this Old World seed bug from Richmond, British Columbia in 1966 as the first record from North America. We have now been able to assemble collection records and appropriate illustrations to document the identity of this species and distinguish it from the similar *D. unus* (Say), a species native to eastern North America. A revised key to the

Western Hemisphere species of the genus *Drymus* Fieber is included to assist in identification.

Measurements (in millimeters) given in the description below are mean and range (in parentheses) from nine specimens of each sex examined from the Old World. Unless otherwise stated, all material is in the Scudder personal collection.

DESCRIPTION

Drymus brunneus (Sahlberg)

Rhyparochromus brunneus Sahlberg 1848, Monogr. Geoc. Fenn.:57

Pachymerus pallidus Herrich-Schaeffer 1853, Wanz. Ins. 9:211 (Synonym)

Drymus notatus Fieber 1861, Europ. Hem. :179 (Synonym)

Drymus brunneus, Stål 1862, Ofv. Vet. Akad. Forh. 19:217 (Current combination)

Drymus brunneus, Slater 1964, Cat. Lyg. World 2:884 (Bibliography)

Drymus (Sylvadrymus) brunneus, Péricart 1998, Faune de France 84B:255 (Description)

Macropterous or submacropterous, robust, subglabrous, and somber coloured. Head and anterior lobe of pronotal disc dark ferruginous brown to black; rest of dorsum and venter dark ferruginous; corium with basal third tending to be pale ferruginous to ochraceous, with a more or less distinct pale spot in middle at junction with uniform darker apical two-thirds of corium; antenna ferruginous to dark

ferruginous with apical half of third segment dark brown, and apical half of fourth segment pale ferruginous; legs ferruginous, with femora darker.

Head and anterior lobe of pronotal disc closely punctate; posterior lobe of pronotal disc and scutellum with larger more dispersed punctures. Head width ♂ 0.87 (0.80-0.92) ♀ 0.92 (0.83-0.95); first antennal segment exceeding apex of head by half its length; second antennal segment with short semi-decumbent pubescence, but with longer outstanding setae confined to apical one-fifth; third and fourth antennal segment as thick as or thicker than apex of second segment, with third segment somewhat thicker in apical half and slightly spindle-shaped; fourth antennal segment in middle as thick as widest part of third segment; third and fourth antennal segments with long erect setae, in addition to shorter, more dense, decumbent pubescence along most of length; second antennal

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segment shorter than head length; on average second antennal segment 0.94 times head width, and about 1.3 times length of third antennal segment; fourth antennal segment on average about 1.2 times length of third antennal segment; antennal measurements ♂ 0.47 (0.43-0.48); 0.74 (0.60-0.78); 0.57 (0.53-0.58); 0.68 (0.63-0.72) ♀ 0.48 (0.43-0.53); 0.77 (0.70-0.80); 0.58 (0.50-0.60); 0.68 (0.67-0.70); rostrum attaining middle coxae.

Pronotum with disc rather convex; with shallow transverse impression on disc just behind middle, this impression level with concave impression on narrowly carinate lateral margins; on average pronotal width about 1.4 times pronotal length; pronotal width ♂ 1.40 (1.28-1.47) ♀ 1.49 (1.27-1.60), pronotal length ♂ 1.03 (0.92-1.10) ♀ 1.03 (0.87-1.10). Hemelytron with costal margin distinctly convex; corium widest just beyond middle, level with apex of clavus; membrane reaching middle of last abdominal tergum or just surpassing apex of abdomen. Fore femora with a single, minute, ventral spine in apical half; tibiae lacking long, erect setae.

Total length ♂ 4.19 (3.80-4.40) ♀ 4.54 (4.40-4.80).

Material examined. (a) Old World: ENGLAND: 3♂ 2♀, Berks, Cothill, 10.viii.1957 (G.G.E. Scudder); 1♂, Berks, Wytham Wood, 30.v.1957 (G.G.E. Scudder); 1♀, Oxon, Bald Hill, ix.1962; 1♀, Surrey, Oxshot, 28.vii.1957 (G.G.E. Scudder). RUSSIA: 2♂ 2♀, Moscow Distr., Birch Grove, 4.viii.1968 (G.G.E. Scudder). SCOTLAND: 2♂ 2♀, Dalkeith, Midlothian, 6.ix.1957 (R.A. Crowson); 1♂, Fullerton Est., Troon Ayrshire, 13.ix.1957 (R.A. Crowson); 1♀,

Invernesshire, Kinveachey, mixed birch and pine litter, 15-19.vii.1957 (R.A. Crowson). (b) New World: CANADA: 2♂ 1♀, B.C. Delta, Alaksen Res., CWS property, pitfall trap, 1.vii-28.viii.2009 (A. Caldicott and B. Bains) [Royal British Columbia Museum, University of British Columbia]. 1♂ 3♀, B.C., Richmond Nature Park, 23.vi-13.vii.1996 (L. Humble, J. Seed) [Pacific Forestry Centre, Victoria; Scudder Coll.]. 1♂ 2♀, BC, Coquitlam, Westwood Plateau, North Hoy Creek Park, 49°19'7.61"N, 122°47'38.18"W, 29.viii.2010 (T. Loh) [UBC; T. Loh Coll.]; 1♀, id., 25.ix.2010, ex: leaf litter, (T. Loh) [T. Loh Coll.]; 3♂ 1♀, BC, Vancouver, Pacific Spirit Park, 49°16'14.51"N, 123°14'12.26"W, 12.viii.2010 (T. Loh) [CNC; UBC; T. Loh Coll.]; 1♀, BC, Coquitlam, Westwood Plateau, Near North Hoy Creek, 49°18'1.03"N, 122°47'21.03"W, 8.v.2010 (T. Loh) [T. Loh Coll.]; 1♂, BC, Coquitlam, Upper Coquitlam River Trail, 49°18'5.26"N 122°46'1.31"W, 24.vii.2010 (T. Loh) [T. Loh Coll.]; 1♀, BC, Port Coquitlam, Coquitlam River Park, 49°17'1.88"N, 122°46'22.94"W, 5.viii.2010 (T. Loh) [T. Loh Coll.]; 1♂ 1♀, BC, Coquitlam, Upper Coquitlam River Park, 49°19'36.41"N, 122°46'22.48"W, 13.x.2010 (T. Loh) [UBC; T. Loh Coll.]; 1♂ 1♀, BC, Coquitlam, Westwood Plateau, 49°17'51.66"N, 122°47'2.20"W, 18.ix.2010 (T. Loh) [T. Loh Coll.]; 1♀, id., 14.viii.2010, (T. Loh) [T. Loh Coll.]; 1♂, BC, Coquitlam, Coquitlam River Park, 49°17'6.04"N, 122°46'31.77"W, 20.x.2010 (T. Loh) [UBC]; 1♀, id., 29.vii.2010 (T. Loh) [T. Loh Coll.]. 2♂, Surrey, Crescent Park, 49°2.904'N 122°51.647'W, Pitfall trap CPI, 5.viii-5.x.2010 (J. Heron, L. Parkinson) [Royal British Columbia Museum].

DISCUSSION

The material from British Columbia compares well with the description in Péricart (1998). It also closely resembles the colour illustration in Southwood and Leston (1959). However, most of the New World specimens are fully macropterous, and measurements are at the upper limits of the range represented in the Old World material examined. Indeed, the pronotum of the specimens measured from Richmond, BC, are both slightly wider and slightly longer than the Old World specimens studied.

Three of the Richmond, BC, specimens were captured in a multiple funnel trap (Lindgren 1983) baited with a high-release rate ethanol lure (EBT 1996-0146-06) and one was obtained in an unbaited 4-panel window pane trap (EBT 1996-0149-03), during studies of introduced and native Scolytidae in southwestern British Columbia (Humble 2001). Trapping was conducted in the west block of the Richmond Nature Park (49°10'19.5"N 123°05'50"W) that preserves the last remnants of the Greater Lulu Island

Bog. A shore pine/Sphagnum moss community predominates with the dominant tree species being European white birch (*Betula pendula* Roth), as well as hybrids with the relatively uncommon native white birch (*B. papyrifera* Marsh.), together with shore pine (*Pinus contorta* var. *contorta* Dougl.). Much of the study area has been invaded by a dense growth of highbush blueberry (*Vaccinium corymbosum* L.).

The Surrey, Crescent Park locality was in the northwest side of the park. This is a forested area of mostly second growth forest, with some manicured fields.

Most of the specimens in the T. Loh collection were obtained by sifting forest leaf litter, especially around logs or near tree stumps. Some were sifted or washed from moss and litter in wet areas near forest headwater streams (Hoy Creek specimens). Specimens from Pacific Spirit Park in Vancouver, BC, were collected mainly from forest communities dominated by red alder (*Alnus rubra* Bong.). Coquitlam specimens came primarily from forests with mixed hardwood (*Alnus*, *Populus balsamifera* *trichocarpa* (T.&G.) Brayshaw, *Acer*) and conifers (*Tsuga heterophylla* (Raf.) Sarg., *Thuja plicata* Donn, *Pseudotsuga menziesii* (Mirb.) Franco). A few were collected from a forest clearing in a backyard on Westwood Plateau, a suburban residential neighborhood in Coquitlam, BC. The location coordinates for most of these records (especially in the parks) are approximate and do not reflect the actual location where the specimens were found.

Southwood and Leston (1959) noted that *D. brunneus* in the British Isles frequents damp places, and is usually found on the ground amidst litter and mosses, sometimes in *Sphagnum*. The Richmond area of British Columbia is on the coast, close to industrial sites, where other adventive insects have been detected.

According to Péricart (1998), *D. brunneus* is largely a Euro-Siberian species, widely distributed in the eastern Palaearctic, with a range extending into Asia. Slater (1964) and Péricart (1998) give details of the known distribution in the Old World. The species almost certainly was introduced into North America from the Palaearctic and may represent a recent accidental introduction.

Drymus brunneus runs to the genus *Drymus* Fieber in the key to the genera of North American Drymini in Ashlock (1979). It is very similar to *D. unus* (Say), a widely distributed native species in eastern North America (Ashlock and Slater 1988). However, these two species differ in the coloration of the hemelytra and in the setation on the second antennal segment. While both species are often submacropterous, and have the costal margin of the corium distinctly convex and the widest area of the corium level with the apex clavus. The apical half of the corium is uniform chocolate brown and without a pale central spot in *D. unus* (Figure 1), whereas in *D. brunneus* there is usually a distinct pale spot in the centre of the basal third of the corium, adjacent to the border of the darker apical area (Figures 2 and 3).

Furthermore, in *D. brunneus* the second antennal segment has long erect setae confined to the apical one-fifth (Figures 4 and 5), whereas such long erect setae occur along the whole length of the second antennal segment in *D. unus* (Figure 6).

The key to the Western Hemisphere species of *Drymus* given by Slater and Brailovsky (1997) can be modified to include *D. brunneus* as follows:

Revised key to Western Hemisphere species of *Drymus*

1. Distal half of fourth antennal segment white, strongly contrasting with dark coloration of basal half of antennae; explanate lateral margins of pronotum broad, subequal to width of second antennal segment; second antennal segment subequal to head length.....*mexicanus* Slater & Brailovsky
Fourth antennal segment unicolorous dark brown to black, or if distal half pale, not white and strongly contrasting with dark coloration of basal half of antennae; explanate lateral margins of pronotum relatively narrow, much narrower than width of second antennal segment; second antennal segment considerably longer than head length.....2

2. Large, 6.5-7mm; very dark brown to almost black; anterior and posterior lobes of pronotal disc nearly evenly punctate; expanded lateral margins of pronotum concolorous with dorsal surface of pronotum.....*crassus* Van Duzee
Smaller, under 5.5 mm; dull brown to ferruginous brown; anterior lobe of pronotal



Figure 1-6. Figs. 1-3. Dorsal view: 1. *Drymus brunneus* (Sahlberg) ♀, British Columbia, Canada, Richmond Nature Park, EBT96-0146-06, 23.vii-13.viii.1996 (L. Humble, J. Seed) [Scudder Coll.]; 2. *Drymus brunneus* ♂, Dalkeith Midlothian, UK, 6.ix.1957 (R.A. Crowson) [Scudder Coll.]; 3. *Drymus unus* (Say) ♀, ONT, Canada, Hilton Beach, Sugar Maple Forest, Pan trap, 16.ix-14.x.1989 (J.E. Swann) [Scudder Coll.]; Figs. 4-6. Detailed structure of second antennal segment: 4. *Drymus brunneus*, BC specimen; 5. *Drymus brunneus*, UK specimen; 6. *Drymus unus*, Ontario specimen. Photos by Don Griffiths.

disc more finely punctate than posterior lobe; expanded lateral margins of pronotum usually slightly paler than surface of anterior pronotal lobe.....3

3. Second antennal segment with long erect setae confined to the apical one fifth and not distributed along whole length; basal third of corium usually with a distinct pale spot at

margin of darker apical two-thirds.....*brunneus* (Sahlberg)
Second antennal segment with long erect setae distributed along whole length of segment; basal third of corium without a distinct pale spot at margin of darker apical two-thirds.....*unus* (Say)

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Asciodema obsoleta (Hemiptera: Miridae): New Records for British Columbia and First U.S. Record of an Adventive Plant Bug of Scotch Broom (*Cytisus scoparius*; Fabaceae)

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ABSTRACT

The European plant bug *Asciodema obsoleta* (Fieber) develops mainly on Scotch broom, *Cytisus scoparius* (L.) Link; it is one of several broom insects that apparently have been introduced to North America with shipments of nursery stock. This mirid first was reported in North America from British Columbia (Vancouver, Vancouver Island, Bowen Island) in 1966, but no additional records have been published. Based on specimens in BC museums and our recent field work, we extend the previously recorded BC distribution of *A. obsoleta* and provide the first U.S. record: Washington State (Point Roberts, Whatcom County).

Key Words: Canada, Palearctic immigrant, distribution, new U.S. record, *Laburnum anagyroides*, host plants

INTRODUCTION

Scotch broom (hereafter broom), *Cytisus scoparius* (L.) Link; Fabaceae), is a genistoid legume (tribe Genisteae, subfamily Faboideae) native to central and southern Europe. Introduced to coastal British Columbia as an ornamental in the 1850s, the plant became naturalized, mostly along or near roadsides on the Lower Mainland, Vancouver Island, and some Gulf Islands. Although broom no longer is planted along BC highways for ornament and slope stabilization, it has become sufficiently invasive in the Pacific Northwest to hinder reforestation and threaten native biodiversity, particularly in Garry oak and grassland ecosystems (Zielke *et al.* 1992, Peterson and Prasad 1998, Coombs *et al.* 2004, Haubensak and Parker 2004). Biological control efforts began in the 1950s, and several European insects of broom began to be released in the 1960s in California, Oregon, and Washington (Andres and Coombs 1995, Coombs *et al.* 2004).

Insects of broom are especially well known in England. From the mid-1950s to the mid-1960s, broom insects were studied intensively at Silwood Park (near Ascot, Berkshire, SW of London) by J.P. Dempster, O.W. Richards, N. Waloff and others at

Imperial College, London. Among the 35 insects consistently found on broom were 13 species of Hemiptera. Particular attention was given to the bionomics of the mirids *Asciodema obsoleta* (Fieber), *Heterocordylus tibialis* (Hahn), *Orthotylus adenocarpus* (Perris), *O. concolor* (Kirschbaum), and *O. virescens* (Douglas and Scott) (Waloff and Southwood 1960, Dempster 1964, Waloff 1968). The *Orthotylus* species and *H. tibialis* (subfamily Orthotylinae) essentially are restricted to broom, whereas *A. obsoleta* (subfamily Phylinae) also develops on gorse (*Ulex europaeus* L.), another genistoid legume. All five mirids are univoltine and overwinter as eggs, with their oviposition sites not overlapping substantially. Eggs hatch sequentially from March (sometimes April) to mid-June; adults first appear from about mid-May to mid-July, and, although all species can be found concurrently on broom, their periods of peak abundance differ; and all are omnivores that feed on the host and arthropods such as aphids and psyllids (Waloff and Southwood 1960, Dempster 1964, Waloff 1968).

Three of the British broom Miridae—*A. obsoleta*, *O. concolor*, and *O. virescens*—were

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accidentally introduced into the Pacific Northwest, probably with imported nursery stock (Waloff 1966, Wheeler and Henry 1992). Both species of *Orthotylus* are recorded from British Columbia and Pacific U.S. states (Wheeler and Henry 1992), but published BC records of *A. obsoleta* have been limited to Waloff's (1966) original North American study. The earliest collection was from Vancouver (University of British Columbia campus), 6.vii.1959, by G.G.E. Scudder (Barnes *et al.* 2000). Syrett *et al.* (1999) erroneously attributed the first North American record of *A. obsoleta* to Downes (1957). Waloff (1966), during field work in June and July 1963, recorded *A. obsoleta* from Vancouver (UBC), Vancouver Island (near Victoria), and Bowen Island (Howe Sound

NW of Vancouver); surveys for the mirid in the Fraser Valley (and in California) were negative. Syrett *et al.* (1999) updated the status of European insects established on broom in the Pacific Northwest, noting that no new information was available for *A. obsoleta*.

Here we extend the known distribution of *A. obsoleta* in BC, report Washington State as the first U.S. record, and give golden chain tree (*Laburnum anagyroides* Medik.; Fabaceae) as a new host record. We use the name *A. obsoleta* rather than *A. obsoletum* because the genus *Asciodema*, considered neuter by Steyskal (1973), is considered feminine in the most recent world (Schuh 1995) and Palaearctic (Kerzhner and Josifov 1999) catalogs of the Miridae.

MATERIALS AND METHODS

We collected *A. obsoleta* in late June of 2010 and 2011 during efforts to update the distributions of European Hemiptera of broom in the Pacific Northwest (Wheeler and Lattin 2008, Hoebeke and Wheeler 2010, Wheeler and Hoebeke 2012). The mirid was collected into small plastic vials after broom was swept or its branches were beaten over a shallow net. In June of both years *A. obsoleta* dominated the plant bug fauna of broom in BC. The only other mirid present as late instars and adults was *O. virescens*, whose eggs hatch later than those of *A. obsoleta* (Waloff and Southwood 1960). Nymphs of *A. obsoleta* could be separated in the field from those of *O. virescens* by their darker color, the indistinct opening of the dorsal abdominal scent gland, and overall different Gestalt of the late instars.

Under magnification, the parempodia (= arolia) of *A. obsoleta* appear hairlike (setiform) rather than fleshy and apically convergent, as in *O. virescens*. Fourth or fifth instars (n = 5) identified in the field as *A. obsoleta* and reared to adulthood all proved to be that species; similarly, the identity of two fifth instars of *O. virescens* was confirmed through rearing. All collections presented below (Specimens examined) were made by the authors and, unless noted otherwise, *Cytisus scoparius* was the host plant. Nymphs are recorded only by the instars observed, e.g., IV–V. Voucher material of *A. obsoleta* is deposited in the Cornell University Insect Collection (Ithaca, NY) and the National Museum of Natural History, Smithsonian Institution (Washington, DC).

RESULTS AND DISCUSSION

Museum records. Several unpublished records of the mirid are available, based on specimens in the Canadian National Collection of Insects, Agriculture and Agri-Food Canada, Ottawa, ON (CNC); Royal British Columbia Museum, Victoria, BC (RBCM); and Spencer Entomological Collection, Beaty Biodiversity Centre, University of British Columbia, Vancouver, BC (UBC): *Lower Mainland*: Burnaby Lake, Burnaby, 9.vii.1998, D.J.M. Quiring, 1♀ (CNC); Vancouver, 7.vii.1977, J.A. van

Reener, 5♀ (UBC); *Southern Gulf Islands*: Galiano Island, north end, 24.vi.1989, G.G.E. Scudder, *Cytisus scoparius*, 1♂; *Vancouver Island*: Jordan River, 27.vii.1988, G.G.E. Scudder, *C. scoparius*, 1♂; 19 km E of Jordan River, 27.vii.1988, G.G.E. Scudder, *C. scoparius*, 1♀ (CNC); Metchosin, Camas Hill summit, 29.viii.–5.ix.1999, L. & C. Rosenblood, 1♂, 9♀ (RBCM).

Field surveys. On the Lower Mainland of BC, we found *A. obsoleta* in the Greater (Metro) Vancouver area (Delta, Langley,

Lions Bay, Surrey, and West Vancouver) as far south as the Tsawwassen community of Delta; the plant bug also was found north of Vancouver at Squamish and east in the Fraser Valley at Deroche. Additional field work probably would show that the mirid is established farther north and east of Vancouver than is indicated by our limited sampling. Collections on Vancouver Island were made from Victoria to just north of Ladysmith. The first U.S. record is based on the collection of late instars and adults at Point Roberts, a small area (~12.7 km²) of Washington State (Whatcom Co.) that is cut off from the mainland.

We sampled broom on nearly the same dates in both years: 26–30.vi.2010 and 22–28.vi. 2011. Populations might have been slightly advanced in 2010, with more adults, few of which were teneral, and fewer late-instar nymphs compared with 2011. Earlier instars (II–III) were observed only in 2011 at two sites north of Vancouver. The presence of fifth instars and teneral adults on golden chain tree (*Laburnum anagyroides*), another genistoid legume, suggests that this small Palaearctic tree can serve as a host plant. At all three sites where *A. obsoleta* was found on *L. anagyroides*, broom was present within 100 m. More field work is needed to determine whether the mirid can complete its development on *Laburnum* and if this plant association persists.

Specimens examined. CANADA: British Columbia, Abbotsford, 49°02.387'N 122°16.306'W, 26.vi.2011, 3♂, 5♀, IV–V; Abbotsford, 49°03.609'N 122°17.177'W, 27.vi.2011, 6♂, 2♀, IV–V; Delta, nr Boundary Bay Airport, 49°04.938'N 123°00.096'W,

27.vi.2010, 2♀; Delta, Ladner, 49°05.413'N 123°02.618'W, 27.vi.2010, 3♂, 5♀, V; Delta, Tsawwassen Ferry Causeway, 49°01.400'N 123°06.293'W, 22–23.vi.2010, 4♂, V; Deroche, 49°11.454'N 122°04.062'W, 26.vi.2011, IV–V; Langley, 200th St. & 56th Ave., 49°06.454'N 122°40.143'W, 28.vi.2011, 2♂, 1♀, IV–V; Lions Bay, 49°27.211'N 123°14.253'W, 27.vi.2011, 1♂, IV–V; E of Mission, River Rd. S of Rt. 7, 49°08.919'N 122°11.018'W, 26.vi.2011, IV–V; Porteau Point, Rt. 99, 49°32.711'N 123°14.430'W, 27.vi.2011, II–IV; Squamish, 49°41.968'N 123°09.067'W, 27.vi.2011, III–V; Surrey, Guildford, 100th Ave. nr 140th St., 49°10.994'N 122°50.195'W, 26.vi.2010, 2♂, 14♀, V; Surrey, 16th Ave. & 192nd St., 49°01.871'N 122°41.552'W, 28.vi.2011, 1♂, IV–V; Vancouver Island, Chemainus, 48°55.701'N 123°43.257'W, 30.vi.2010, 1♂, 2♀ ex *Laburnum anagyroides*; Vancouver Island, Ladysmith, Transfer Beach Park, 48°59.352'N 123°48.552'W, 30.vi.2010, 1♂, 2♀, V; Vancouver Island, Rt. 1, 5 km N of Ladysmith, 49°02.293'N 123°51.938'W, 28.vi.2010, 2♂, 6♀; Vancouver Island, Saanich, Mount Tolmie Park, 48°27.449'N 123°19.375'W, 29.vi.2010, 5♂, 5♀; Vancouver Island, Victoria, Burnside Rd. W & McKenzie Ave., 48°27.741'N 123°24.172'W, 29.vi.2010, 4♂, 5♀, V ex *L. anagyroides*; West Vancouver, Eagle Harbour, Westport Rd., 49°21.627'N 123°15.463'W, 28.vi.2010, 5♂, 1♀, V ex *L. anagyroides*; West Vancouver, Marine Dr., Whytecliff Park, 49°22.297'N 123°17.426'W, 28.vi.2010, 5♀. UNITED STATES: Washington, Whatcom Co., Point Roberts, 48°58.811'N 123°04.209'W, 24.vi.2011, 3♂, 1♀, IV–V.

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SCIENTIFIC NOTE

Mortality of *Metarhizium anisopliae*-infected wireworms (Coleoptera: Elateridae) and feeding on wheat seedlings are affected by wireworm weight**WILLEM G. VAN HERK¹ and ROBERT S. VERNON¹**

As some wireworm species are notorious pests of common wheat, *Triticum aestivum* (Vernon *et al.* 2009), a small study was conducted at the Pacific Agri-Food Research Centre (PARC) in Agassiz, BC in August 2009, to determine whether the number of germinating wheat seedlings (cv. AC Barrie) killed by the dusky wireworm, *Agriotes obscurus*, is affected by the number and size of the wireworms that seedlings are exposed to. An unexpected factor appeared at the end of the study in that many wireworms were infected with *Metarhizium anisopliae*, resulting in considerable mortality. This factor precluded us from meeting some of the initial objectives of the experiment, but still allowed us to determine if mortality of seedlings was affected by wireworm weight and number, and if mortality of the wireworms from *M. anisopliae* infection was affected by their weight.

We filled 160 500 ml circular (dia = 11 cm, height = 8 cm) plastic containers (Plastipak Industries, Inc., La Prairie, QC) with 500.0 (+/- 0.2) g of soil collected from a field at PARC, Agassiz in 2009. The soil was sieved through a 2 mm x 2 mm screen to remove rocks and organic material, made up to 20% moisture by weight, and homogenized. Containers with soil were placed in a walk-in cooler set at 15.0 +/- 0.5°C to mimic soil temperature conditions in spring when wheat is normally planted. Wireworms were weighed individually on August 7, and 0-4 wireworms were placed in each container (Table 1). All wireworms were collected at PARC in April 2009 and stored in 40l Rubbermaid tubs without food, at 8-10°C, until 1 wk before the study, when tubs were brought up to room temperature and food baits (a cup of 100 ml moist vermiculite mixed with 10 ml wheat

seed) placed inside. Only mobile wireworms, appearing healthy (Vernon *et al.* 2008) and actively feeding 2 to 3 d prior to placement in the containers were used for this study. Wireworms selected ranged considerably in weight (range: 6.6 to 46.4 mg; Table 1), but all wireworms in individual containers were similar in weight (within 5.0 mg), and an attempt was made to have an equal number of similar sized wireworms for each of the 1, 2, and 3 or 4 wireworm densities to determine the effect of wireworm weight on the number of wheat seedlings killed.

Two days after wireworms were placed in containers, 21 untreated wheat seeds were planted 2 cm deep in small pre-made holes. Seeds were spaced at equal distance (1.75 cm) from each other, in a 3, 5, 5, 5, 3-grid pattern. After planting, groups of eight containers were placed in 26 cm x 47 cm x 6 cm deep nursery flats (Eddi's Wholesale Garden Supplies, Ltd., Surrey, BC), 1.0l cold water added between the containers in the flat, and flats covered with 14 cm high transparent plastic domes (Eddi's Wholesale) to prevent desiccation of the upper layer of soil. After planting, containers were subjected to a 12:12 light:dark regimen.

Seedling emergence was first observed 5 d after planting, stand counts were conducted 8 d (when domes were permanently removed due to the length of plant shoots) and 15 d after planting. Wireworms were removed 25 d after planting and their health evaluated (Vernon *et al.* 2008). This revealed that only 123 of 255 larvae were alive, the rest having died from *Metarhizium* infection, most likely within the first two weeks of the study as evident from the extent of mould formation on the surface of the cadavers. Analysis of the proportion of wireworms dead in each

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Table 1.

Proportion of wheat seedlings dead or not emerging 15 days after planting. N = number of containers. Shown are least squares means and SE estimates calculated from ANCOVA; all least squares means are significantly different from 0 at $P<0.0001$. Numbers followed by different letters in columns are significantly different from each other at $P<0.05$, using a Tukey-Kramer adjustment.

No. of wireworms in container	N	Wireworm weight range (mg)	Model 1: All wireworms placed in containers	N	Model 2: Surviving wireworms alone
0	43		0.084(0.018)A	80	0.113 (0.009) A
1	43	6.6 - 46.4	0.101(0.012)A	50	0.151 (0.012) AB
2	36	8.6 - 42.3	0.166 (0.013) B	21	0.202 (0.018) BC
3	12	25.8 - 43.7	0.233 (0.023) BC	5	0.246 (0.037) BC
4	26	8.2 - 41.3	0.250 (0.014) C	4	0.313 (0.041) C
ANCOVA		Flat:	F=1.18, df=19,135, P=0.28		F=0.97, df=19,135, P=0.50
Statistics		No. of wireworms:	F=25.15, df=4,135, P<0.0001		F=11.51, df=4,135, P<0.0001
		Wireworm weight:	F=0.51, df=1,135, P=0.47		F=16.78, df=1,135, P<0.0001

container with ANCOVA (PROC GLM, SAS 9.1) with variable container flat and covariate average wireworm weight in containers, indicated that flat did not have a significant effect ($F=0.91$, $df=19,96$, $P=0.57$), but wireworm weight did ($F=14.17$, $df=1,96$, $P=0.0003$). Eliminating the variable flat from the analysis and regressing the proportion of wireworms dead to the average wireworm weight in each container produced the following model: Proportion dead = $0.107 + 0.015 \times \text{wireworm weight}$ ($SE = 0.099, 0.004$; $t=1.08, 4.42$; $P=0.28, <0.0001$, respectively; model $R^2 = 0.145$), indicating that the proportion of wireworms dead increased with the average weight of wireworms in the container.

Considering the mortality of wireworms during the experiment, two separate analyses were conducted to determine the effect of wireworm number and weight on wheat seedling survival. In the first analysis, the proportion of wheat seedlings that did not emerge by 15 d after planting was evaluated with ANCOVA, with variables flat and the number of wireworms originally placed in the container, and the covariate average wireworm

weight per container (Table 1, Model 1). Treating the number of wireworms in the container as a variable allowed us to calculate least squares means for the proportion of seedlings killed per wireworm density, and produced a similar model as when both wireworm number and average weight were included as covariates. The second analysis was similar, differing only in that the number of wireworms that survived was included. Both models indicated that the flat in which containers were placed did not have a significant effect on plant mortality ($P>0.05$; Table 1), and that the number of wireworms in the container was highly significant ($P<0.0001$), with the proportion of plants killed increasing with wireworm number (Table 1). The weight of wireworms in the container did not appear to significantly affect the number of plants killed if all wireworms placed in each container were considered. However, as heavier wireworms were more likely to die from *Metarhizium*, and mortality appeared to have occurred early in the study when the wheat plants were most susceptible to wireworm attack, this is probably a misleading conclusion. When only surviving

wireworms are included in the analysis (Table 1, Model 2), it is apparent that heavier wireworms caused more damage than smaller ones. While this confirms the expectation that larger wireworms are more destructive to wheat seedlings than smaller ones, the finding that larger wireworms are more likely to die from *Metarhizium* than smaller wireworms is novel and of importance, as it suggests that using the fungus as a biological control agent for wireworms may be more effective for later than earlier instars. This relationship has

apparently not been observed in wireworms before, and should be confirmed and explained with further study. As *Metarhizium* is commonly present in Agassiz soil, all locally collected larvae likely contain spores and an environmental trigger (e.g. temporary exposure to a high temperature) necessary to induce infection. Considering the LT50 of *A. obscurus* after *Metarhizium* infection, the infection seen here was likely triggered prior to wireworm placement in containers (Kabaluk and Ericsson 2007).

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Symposium Abstracts: INVASION BIOLOGY!

Entomological Society of British Columbia Annual General Meeting, Douglas College, New Westminster, BC, Oct. 15, 2011

Climate change and invasion potential

David R. Gillespie. *Agriculture & Agri-Food Canada, Agassiz, BC*

Climate change and invasive alien species are two of the very large themes in contemporary biology. Climate change will clearly have impacts on the biology of invasive species. How those impacts will change the threats from invasive species is a real concern. Will we cope with more invasive species, and will those species already present cause more injury? Some of the major trends and ideas surrounding these questions will be presented.

Interpreting the effects of a biocontrol weevil released to control houndstongue (*Cynoglossum officinale*) on its target weed and a native nontarget plant.

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Biological control can be a very effective way of reducing the impact of invasive plants, and like any form of pest control includes a risk factor. Non-target attack by a biological control agent is undesirable, but can vary in severity and not always outweigh the damage the invasive host plant would inflict on an area if left uncontrolled.

Approval for release of a weed biocontrol insect is contingent on strong host-specificity. However, feeding and oviposition on related plant species may still occur, and interpreting and predicting this nontarget attack is an important step in assessing potential risks in weed biocontrol. *Mogulones crucifer* (Coleoptera: Curculionidae) is a root-feeding weevil that was approved for release in Canada in 1997 to control houndstongue (*Cynoglossum officinale*, Boraginaceae). Since

its release, *M. crucifer* has frequently been successful in suppressing houndstongue, but it also has been observed attacking native, nontarget Boraginaceae in western Canada.

In 2009, groups of 300 *M. crucifer* were released at nine rangeland sites containing the native nontarget borage, blue stickseed (*Hackelia micrantha*), either growing without houndstongue or interspersed with the weed. Release sites were revisited four to seven weeks later and indications of *M. crucifer* attack were observed on both plant species within a 5 m radius of release. When plants from three sites were harvested and dissected 10 weeks after release, *M. crucifer* larvae were found in both species, but were significantly more abundant in houndstongue (Wilcoxon Rank Sum test, $p=0.0425$). Release sites were revisited in 2010, when attack on houndstongue continued, but indications of nontarget attack were rare. To determine whether nontarget attack observed in 2009 was temporary spillover, or the initial establishment of weevils on nontargets, plants on the 2009 release sites were harvested and dissected in 2011 to quantify the level of target and nontarget attack two years post release. Preliminary results will be presented.

Recent introductions of non-indigenous species in British Columbia

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Recent establishments of invasive insect pests such as the emerald ash borer, Asian long-horned beetle and brown spruce longhorn beetle in Canada have highlighted the threat that such incursions pose to the urban and natural forests of the country. The impacts of non-indigenous introductions generally first occur in urban environs, as a direct consequence of the importation of a wide

range of commodities. Once established in the urban environments, pest populations can expand into the adjacent natural forests. We provide a brief introduction to two pathways for the introduction of non-indigenous species of significance to forestry. The generic composition of the urban trees planted in Vancouver is reviewed and results of various surveys of the insect fauna associated with the urban forests are presented.

More than twenty-five non-indigenous herbivores have been discovered in British Columbia during inventories of the fauna of urban parks and street trees or during the construction of DNA reference libraries for species identification. They include: eight species of Lepidoptera; seven sawflies (Hymenoptera: Symphyta); ten beetles (Coleoptera: Cuculionidae and Cerambycidae) and one gall midge (Diptera: Cecidomyiidae). The hosts and the feeding guilds, overwintering biology, life histories, and native and introduced ranges of these introductions are examined and a preliminary analysis of the probable pathways for their introduction is presented. Evidence for the expansion into natural forest habitats are presented for some species. Canadian and international strategies to prevent the influx of alien invasive species are discussed.

Policy, regulation and invasives: role of CFIA

Gabriella Zilahi-Balogh *Canadian Food Inspection Agency, Kelowna, BC*

The Canadian Food Inspection Agency (CFIA) has a long history of mitigating pest introductions resulting from international trade. With increasing trade and increasing movement of plant products internationally, invasive alien species are an immediate and growing threat to Canada's environment and economy. The mandate of the plant health program within CFIA is to protect plant health and production in Canada by preventing the introduction and spread of quarantine pests that threaten Canada's agriculture, forestry and horticultural resources through science based regulation and enforcement. Examples of measures used to mitigate the introduction and spread of regulated pests into Canada will be provided using the grape industry as an example.

The European fire ant (*Myrmica rubra*) in British Columbia

Robert Higgins *Thompson Rivers University, Kamloops, BC*

The identification of the European fire ant (*Myrmica rubra*) in North Vancouver in the fall of 2010 marks the first determination of this pest ant west of southern Ontario, in Canada, and above 49°N latitude in North America. Since this first identification, this ant has also been confirmed in Burnaby, Vancouver, and Victoria. The European fire ant is anthropogenic, most likely being introduced in landscaping plants and then spreading densely through lawns, raised garden beds, small homeowner cold-frames and greenhouses. This ant swarms rapidly when disturbed (e.g., lawn mowing) and, unlike most ant species in BC, readily and noticeably stings. In this presentation, the introduction of this species to North America will be reviewed. The natural history of this ant will be discussed, especially where this differs from that of its native range, and helps to explain the manner in which colonies spread once established. Further, management strategies will be considered, particularly in the context of urban neighbourhoods.

Spotted wing *Drosophila* (*Drosophila suzukii*): Update for coastal British Columbia, Oct 15, 2011.

Tracy Hueppelsheuser *British Columbia Ministry of Agriculture*

Spotted wing *Drosophila* (*Drosophila suzukii*, SWD) has been present in British Columbia fruit growing areas and the Western United States since 2009. SWD is a temperate fruit fly, which infests ripening fruit before harvest. Infested fruit is not unmarketable. SWD infests a wide range of thin-skinned fruit including blueberries, strawberries, raspberries, blackberries, cherries and grapes.

There are several non-crop hosts of SWD in BC; the primary concern in coastal BC is Himalayan blackberry *Rubus discolor*.

2011 Fraser Valley trapping results indicate that the SWD population was lower and later than in 2010. In 2011, presence of larvae in harvested fruit was not detected until mid August, compared to late July in 2010.

Harvested raspberry and blueberry fruit can be evaluated for larval infestation by submerging a known amount of fruit in a

solution of sugar or salt of adequate concentration.

SWD flies were caught throughout the winter of 2010/11, with the highest catches in hedgerows – unmanaged mixed vegetation adjacent to commercial fields. The lowest catches were at building sites. Trap catches dropped considerably after January, and remained low to nil through the spring. Flies caught from January onward were mostly female.

Spotted wing *Drosophila* in the southern interior valleys of British Columbia, 2010-2011

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Spotted wing drosophila, *Drosophila suzukii*, was first detected in the interior of British Columbia in September 2009. Adult populations were monitored with extensive networks of apple cider vinegar-baited traps in 2010 and 2011. In 2010, *D. suzukii* was widespread in the Okanagan and Similkameen valleys, present in the Creston Valley, and damage was reported in cherry, peach, nectarine, apricot and berry crops as well as domestic small fruit. In 2011, lower population levels were recorded in the Okanagan and Similkameen valleys than in 2010, none was found in the Creston valley and there were no reports of economic damage in commercial fruit. New hosts recorded in the southern interior valleys of B. C. to date are Oregon grape, blue elderberry, northern black currant, honey suckle, Mahaleb cherry and ornamental elderberry.

Presentation Abstracts

Entomological Society of British Columbia

Annual General Meeting,

University of the Fraser Valley, Abbotsford, BC, Oct. 14, 2011

Olfactory responses of *Micromus variegatus* (Neuroptera: Hemerobiidae) to pepper leaves infested with *Myzus persicae* and *Aulacorthum solani* (Homoptera: Aphididae).

Rob McGregor & Chloé Hemsworth *Institute of Urban Ecology, Douglas College*

Micromus variegatus (Neuroptera: Hemerobiidae) is being evaluated for biological control of pest aphids on greenhouse-grown peppers in BC. Responses of adult females to the odours of pepper leaves infested with *Myzus persicae* and *Aulacorthum solani* (Homoptera: Aphididae) were conducted using y-tube olfactometers. *M. variegatus* females show a slight preference for the odour of *M. persicae*-infested leaves vs. clean plant odours. No similar preference was recorded for the odour of *A. solani*-infested leaves vs. clean plant odours. Results are discussed as they relate to the use of *M. variegatus* for biological control

of *M. persicae* and *A. solani* in BC pepper greenhouses.

Cryptic diversity of a candidate weed biological control agent

Chandra E. Moffat, Robert G. Lalonde & Jason Pither *Department of Biology, University of British Columbia, Kelowna BC*

We surveyed host plant use of a candidate weed bio-control agent (a gall wasp), for invasive hawkweeds, in its native range of Central Europe. Despite gall occurrence on multiple host species, when suitable species co-occurred we found that host use was significantly non-random, with only the most abundant species being utilized.

Update on Balsam woolly adelgid in BC

Gabriella Zilahi-Balog *Canadian Food Inspection Agency, Kelowna, BC*

The balsam woolly adelgid was accidentally introduced into North America

from Europe in the early 1900s. It is a pest of *Abies* sp. and infested trees have reduced vigor, growth that can eventually result in tree mortality. This pest is regulated both provincially and federally. The history of balsam woolly adelgid in BC, biology, regulations and recent detections outside the current quarantine zone will be discussed.

Cool Caterpillars: Low Temperature Biocontrol of A Climbing Cutworm

T. Scott Johnson¹, Tom Lowery², Joan Cossentine², and Jenny Cory¹ ¹*Department of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6 Canada* ²*AAFC, Pacific Agriculture Research Centre, 4200 Highway 97, Summerland, BC V0H 1Z0 Canada.*

Abagrotis orbis is a climbing cutworm pest in the vineyards of the Okanagan. Much of their active feeding periods occur under cooler temperatures. We evaluated their susceptibility to several entomopathogenic fungi and nematodes across three temperatures. The larvae were susceptible to entomopathogenic fungi and nematodes with the highest mortality rates occurring at higher temperatures, though significant mortality took place at lower temperatures.

Resistance to *Bacillus thuringiensis* alters macronutrient selection, regulation and utilization in the cabbage looper, *Trichoplusia ni*: Effects on performance and disease resistance

Ikkei Shikano and Jenny Cory *Department of Biological Sciences, Simon Fraser University*

Nutritional qualities of host plants affect both insect performance and condition. Previous studies have shown that Bt-resistant *Trichoplusia ni* exhibit significant developmental costs when reared on certain host plants. We examined whether susceptible and Bt-resistant *T.ni* select, regulate and use macronutrients differently, and how such differences may influence performance and susceptibility to Bt challenge.

The influence of natal host on the fecundity of the parasitoid, *Praon unicum*, on the blueberry aphid, *Ericaphis fimbriata*

Erfan Vafaie¹, Sheila Fitzpatrick², Jenny Cory¹ ¹*Department of Biological Sciences, Simon Fraser University, 8888 University Drive.*

Burnaby, BC, V5A 1S6 Canada ²*AAFC, Pacific Agriculture Research Centre, 4200 Highway 97, Summerland, BC V0H 1Z0 Canada.*

We studied the effects of rearing *Praon unicum* on an alternative host, *Myzus persicae*, on its ability to parasitize novel aphid hosts. A combination of potential/realized fecundity, and fitness proxies were used to determine the impact of an alternative host and are discussed in the context of augmentative control.

Identifying feeding attractants from showy milkweed flowers for potential control of the apple clearwing moth

Eby, C¹; Gardiner, M²; Gries, R¹; Judd, G²; Gries, G¹ ¹*Simon Fraser University, Department of Biological Sciences, Burnaby, BC* ²*Pacific Agri-Food Research Centre, Summerland, BC*

Adult *Synanthedon myopaeformis*, an exotic pest of apples in BC, commonly feed on showy milkweed flowers. Candidate feeding attractants captured using floral headspace analyses were identified using GC-EAD and proboscis extension assays. A single chemical was shown to be highly attractive to both males and females in field trapping assays.

Supporting Butterfly Conservation in British Columbia: The BC Butterfly Atlas

Patrick Lilley *Raincoast Applied Ecology, Vancouver, BC*

Mapping biodiversity information is invaluable for the conservation of species and their habitats. Involving citizens can extend the reach of survey projects while also making nature more accessible and fun. Following on the success of the BC Breeding Bird Atlas and butterfly atlasing projects in other jurisdictions, the BC Butterfly Atlas is a multi-year effort to inventory and assess the status of butterflies in British Columbia. The BC Butterfly Atlas aims to establish a network of observers to observe, record, and report butterfly sightings from across the province. Results will be combined with existing butterfly records to create an online atlas documenting the distribution of butterflies in BC. Like the Breeding Bird Atlas, participation from a broad range of volunteer observers, from amateurs to experts, will be

key to the success of the project. This talk will introduce the elements of the BC Butterfly Atlas project and discuss opportunities for participation and involvement.

Estimating the impact of arthropod predators preying upon lygus nymphs in the Peace River region of Canada.

Letitia Da Ross & Jennifer Otani *Agriculture & Agri-Food Canada, Beaverlodge Research Farm, Beaverlodge, AB*

Lygus bugs are native pests that are often found in abundance, feeding on canola buds and pods. To estimate potential predation pressure on lygus, four general predators were collected from fields in 2010, then isolated with 3rd, 4th and 5th instar lygus nymphs. The prey preference results of these predators will be presented.

Group morphology affects foraging success in social spiders

Maxence Salomon *Biodiversity Research Centre, UBC, Vancouver*

Social spiders that build communal webs may rely on the architectural properties of their webs to achieve foraging success. I conducted a field experiment to examine foraging dynamics in two social species of *Anelosimus* spp. spiders that vary in individual and group morphology, and show that foraging success depends both on the functional morphology of their communal webs and individual cooperative behaviours.

Update on a few insect species at risk initiatives in British Columbia

Jennifer Heron *British Columbia Ministry of the Environment, 315 – 2202 Main Mall, Vancouver, BC, Canada V6T 1Z1*

Insect conservation is one of the greatest challenges to conservation practitioners. Assessing the conservation status of insect species is more challenging than other species groups, primarily because so little information is available on individual species. Assessing the conservation status involves a number of criteria developed by NatureServe (www.natureserve.org) and the BC Conservation Data Centre (www.env.gov.bc.ca/cdc). Some of the information used to assess a species' conservation status includes 1) inventory and search effort (e.g., including search effort with

no records); 2) species information; 3) provincial, national and global distribution; 4) associated habitat and habitat trends including historic habitat trends and whether the species is associated with an ecosystem at risk; 5) biology and natural history; 6) population sizes And trends; 7) limiting factors and threats; 8) special significance of the species; 9) existing protection including both legislative protection and other status designations; and 10) collections examined. In some instances, a status report is prepared at the provincial level or at national level and incorporates this above information as well as other details about the species.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is the national committee that assesses whether a species should be recommended for listing under the federal Species At Risk Act (SARA) (www.cosewic.gc.ca). To assist COSEWIC status report writers (e.g., provide more information on three insect species currently having national status reports prepared), targeted surveys for three insect species were completed in 2010/11: Western Bumblebee (*Bombus occidentalis*), Audouin's Night-stalking Tiger Beetle (*Omus audouini*) and Western Branded Skipper (*Hesperia colorado oregonia*).

Once a species has been assessed by COSEWIC and listed under the Species At Risk Act (SARA) as extirpated, endangered, threatened or special concern the responsible jurisdiction (e.g., British Columbia) prepares a recovery strategy or management plan that outlines a plan for recovery. The recovery strategy follows science advice given by a group of individuals under a recovery team. Recovery team members include representatives from local stewardship groups, landowners and lands managers, government staff from all levels, researchers and private citizens interested in conservation of the species.

Individuals interested in the recovery of species at risk are encouraged to contact the recovery team chair and either engage in participating on the recovery team or suggest how they would like to become involved or lead recovery actions for the species. Recovery actions are most often linked with reducing threats to the species (e.g., removal of invasive plants that may be contributing to

a decline in host plant growth for a specific butterfly), habitat restoration or studying the species' life history. Recovery actions also link closely with stewardship and local conservation groups, as well as other recovery teams in order to avoid conflicts with recovery actions for other species.

The challenges surrounding invertebrate conservation and the path forward involve engaging numerous agencies, groups, and incorporating initiatives into existing infrastructure. A present provincial invertebrate conservation plan is being drafted, which outlines a broad approach to protecting this species group throughout the province. Part of the recommendations within this plan involves engaging stakeholders and others interested in invertebrate conservation into being part of recovery teams, writing status reports on species they think are possibly at risk, educating people on insect identification and encouraging people to submit records and sightings to the BC Conservation Data Centre. Those interested are encouraged to contact the presenter about how they can contribute to provincial invertebrate conservation initiatives.

Aphid mummies provide parasitoids with a temporal refuge from predation by ladybird *Harmonia axyridis*

F. Simon^{1,2,3} and D. Gillespie² ¹*Simon Fraser University* ²*Agriculture and Agri-Food Canada* ³*University of the Fraser Valley*

Harmonia axyridis is a predatory ladybird, which consumes aphids and parasitoids. This study demonstrates that parasitoid mummies are a refuge from predation. Additionally, *H. axyridis* has differential preference for *Aphidius matricariae* over *Praon unicum*. Consequences of *H. axyridis*' preference will be discussed in the context of biological control and impacts for native aphid-parasitoid systems.

The effects of experience on intermale competition in the western black widow spider

Tanya L.M. Stemberger^{1,2}, Maria Modanu², Maydianne C.B. Andrade² ¹*Department of Biological Sciences, Simon Fraser University* ²*Department of Biological Sciences, University of Toronto Scarborough*

Understanding factors affecting multiple mating by males is critical to assessment of the intensity of sexual selection. We asked whether males with mating experience suffer a decrease in the likelihood of future matings in the western black widow spider (*Latrodectus hesperus*). Males of this species largely cease eating after adulthood, and so have a limited energetic budget for mate searching, courtship and competition. Mating includes a six-hour long, energetically expensive courtship, and at copulation a portion of the male's genitalia breaks off in the female's reproductive tract. Although sexual cannibalism is rare and *L. hesperus* males are physically able to copulate with multiple females, we predicted mating would decrease a male's resource holding potential and the likelihood of remating under competition. We paired once-mated males with size-matched virgin rivals and allowed them to compete for a female. Contrary to predictions, once-mated males won copulations as effectively as their virgin rivals, despite the prior loss of energy to intense courtship and genital trauma. Moreover, in all cases, only one male out of every pair copulated with the female. This suggests mating success may be mediated by female preferences rather than inter-male competition, which may explain why experienced males suffer no disadvantage.

Entomological biocontrol agents of illicit drug plants

Adrian L. Behennah 1829 Laval Avenue, Victoria, BC Canada V8N 1M9

Herbivores of the botanical sources of heroin, cocaine, and marijuana were researched by the UN and the USA during the past 40 years for use as biocontrol agents, including the poppy capsule weevil, *Ceutorhynchus (Neoglocianus) maculaalba*; cocaine tussock moth, *Eloria noyesi* (Lepidoptera: Noctuidae); and hemp flea beetle, *Psylliodes attenuata* (Coleoptera: Chrysomelidae).

A century of outbreaks: tracking the western spruce budworm in BC

Lorraine Maclauchlan Ministry of Forests, Lands and Natural Resource Operations, Kamloops, BC

The story of western spruce budworm (WSB), *Choristoneura occidentalis* Freeman,

in British Columbia reflects the changing climatic and human patterns observed this past century in Douglas-fir, *Pseudotsuga menziesii*, dominated forest environments. WSB has less predictable population fluctuations than other defoliating insects, with outbreaks lasting several years or collapsing after only one to two years. Based upon analysis of stand structure, geographic and topographic features, ecosystems and defoliation history, twelve distinct outbreak regions have been defined. Within these geographic outbreak regions the periodicity of budworm outbreaks is described. BC has records of budworm outbreaks going back to 1909 that help illustrate population fluctuations. The first recorded outbreaks occurred on Vancouver Island in the early 1990s yet no outbreaks have since occurred on the island. Thomson and Benton (2007) attribute the cessation of WSB outbreaks on Vancouver Island as possibly due to warming sea temperatures that promote early larval emergence and thus poor synchrony between insect and host tree. Since the 1930s all WSB outbreaks have occurred in the interior of BC. The Coast Region has experienced very regular, periodic budworm outbreaks since 1940 but the scale of outbreaks has decreased over the past two outbreak cycles. The dry canyon forests near Lillooet have the longest and most regular, chronic, outbreak cycles with five distinct outbreaks in the past century. Each outbreak ranged from a few thousand, to over a hundred thousand hectares of annual defoliation. Although budworm can occur in most Douglas-fir dominated ecosystems, there are still some areas where there appears to be no history of WSB outbreaks.

Budworm is present at low levels in most susceptible forest types. However these insect populations may or may not be able to reach what we define as outbreak proportions unless certain stand conditions are met or some biological or physiological triggers occur. In 2006 MacIaughlan *et al.* reported that there were large areas of susceptible forest type in south and central BC, such as the Cariboo-Chilcotin, where WSB had never reached outbreak levels. The Thompson Okanagan has seen large, often sustained outbreak periods, but these have all occurred within the past three decades. Prior to the 1970s the budworm seldom reached outbreak levels in this region.

Budworm was first mapped in the Cariboo Region in 1974 but only over a small area and no outbreaks were recorded until the late 1990s. Once the budworm population expanded it spread rapidly, mingling with existing endemic populations throughout the Cariboo-Chilcotin. The Cariboo budworm outbreak is one of the largest and most sustained outbreaks ever recorded in BC. The most recent chapter in the budworm saga now has populations expanding north between Williams Lake and Quesnel and into the Kootenay Boundary Region in southern BC. The Quesnel outbreak marks the most northern outbreak yet recorded. Similarly, outbreak populations built in the Princeton and Merritt areas in the past decade where historically there also had been few or no records of outbreak level populations.

The WSB is reacting to our changing climate and increasingly favourable and available host resource. Current budworm outbreaks are distinguished by their expansion into higher elevations and new territory. This change in outbreak dynamics is a response by the insect to milder, more suitable climatic conditions; altered stand conditions; and forests that have little inherent resistance to this insect. As the climate warms, budworm may continue to expand in range toward the limit of its primary host, Douglas-fir.

- MacIaughlan, L.E., J.E. Brooks and J.C. Hodge. 2006. Analysis of historic western spruce budworm defoliation in south central British Columbia. *Forest Ecology Management* 226: 351-356.
- Thomson, A.J. and R.A. Benton. 2007. A 90-year sea warming trend explains outbreak patterns of western spruce budworm on Vancouver Island. *The Forestry Chronicle* 83(6): 867-869.

NOTICE TO CONTRIBUTORS

The JESBC is published once per year in December and articles are also published online as they are accepted. The JESBC is an open-access journal. Manuscripts dealing with all facets of the study of arthropods will be considered for publication provided the content is of regional origin, interest, or application. Authors need not be members of the Society. Manuscripts are peer-reviewed, a process that takes about six weeks.

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